# Rehabilitation and Restoration

After wildfires, Federal, State, and local agencies are concerned with maintaining the quality of water; minimizing the negative impacts of accelerated runoff, erosion, and sedimentation; and ensuring optimal recovery of vegetation and ecosystems. Results of this research are helping managers to apply appropriate and cost-effective restoration and postfire rehabilitation treatments and to develop improved procedures for monitoring treatment effects.

*The proliferation of fire-adapted species, such as cheatgrass in the Great Basin, is negatively impacting ecosystems by increasing fire frequency, intensity, and size.*

The following are NFP rehabilitation and restoration accomplishments for fiscal year 2003:

- Researchers are monitoring the effects of fuel reduction and restoration treatments on the spread of weeds to provide managers with information on the relative risks of choosing alternative vegetation treatments. They adapted and developed landscape invasive plant sampling methods for use in the upper Grande Ronde River basin study area. Researchers also discovered a major, previously undetected landscape-scale invasive plant infestation, *Ventenata dubia* (Leers) Gross. & Dur., or north Africa grass. A new study of *V. dubia* was initiated in cooperation with the Wallowa-Whitman National Forest (*DePuit, 01.PNW.B.1, Pacific Northwest Research Station*).

- Management objectives increasingly require burned areas to be restored by using native plant species, but the availability of these species is low, and little information is available on which native species would work best. Researchers found that post-wildfire rehabilitation on pinyon-juniper woodlands and big sagebrush shrub steppe by aerially seeding grasses was much more effective when the seeding is followed by chaining than when no postfire treatment was administered (*McArthur, 01.RMS.B.2, Rocky Mountain Research Station*).

- Extensive fires in recent years have left entire landscapes vulnerable to weed invasions that in turn dramatically alter fire regimes and negatively impact native plants and animals. A greenhouse pilot study was conducted that assessed alterations in plant primary metabolic processes as indicators of plant biotic stress owing to herbivory by biological control agents. This information will help managers to anticipate and mitigate weedy species invasion (*Markin, 01.RMS.B.3, Rocky Mountain Research Station*).

- The proliferation of fire-adapted species, such as cheatgrass in the Great Basin is negatively impacting ecosystems by increasing fire frequency, intensity, and size. Factors that make ecosystems particularly susceptible to these "invasions" were examined. Researchers developed improved equations for determining fuel loads for Great Basin woodland trees and determined fuel loads for trees in Joint Fire Science Demonstration Area plots. They also developed techniques for safely conducting small-plot burns in Great Basin shrub and woodlands. This information will facilitate development of management techniques that

prevent initial invasions and curb expansions (*Chambers, 01.RMS.B.5, Rocky Mountain Research Station*).

- High-elevation white pines (bristlecone, whitebark, and limber pines) are important species that regenerate after fire, help reduce soil erosion, and set the stage for the development of commercially valuable forest types. Researchers demonstrated that limber and bristlecone pines are effective at naturally colonizing and stabilizing the interior of large burned areas where other species cannot. This information will assist managers by identifying and selecting sources of white pine seeds that display hardiness and resistance to the pathogen to ensure economical and ecological restoration of these sites (*Schoettle, 01.RMS.B.6, Rocky Mountain Research Station*).

- Researchers are looking at the effectiveness of tools, such as prescribed fire, in restoring and sustaining native grasslands and reducing the incursion of woody plants. A study was completed by using calorimetry to document population differences in important shrub species and biological soil crusts. It documented the physiological differences in optimal growth temperatures of southern and northern collections, information important for restoration work (*Finch, 01.RMS.B.7, Rocky Mountain Research Station*).

- As nonnative plants become more dominant on both disturbed and undisturbed sites in the interior Pacific Northwest, native plant communities may experience loss of biodiversity, alteration of ecosystem function, and shifts in plant succession patterns. A study was conducted on seeds collected from 10 species of native grasses and 13 species of native forbs (flowering plants). They were sown following a prescribed burn. New germinants indicate the sowing was successful. Methods for postfire rehabilitation and restoration that favor native over nonnative plant viability will be developed and shared with land managers (*Parks, 02.PNW.B.1, Pacific Northwest Research Station*).

- Several watershed models have been developed to predict runoff and sediment yield, but little effort has been directed specifically toward modeling the effects of wildfire and prescribed fire on forest hydrology. A new study site (mountains of northwest Georgia) was established and instrumented (i.e., with streamflow samplers, overland flow samplers, and soil solution lysimeters) to model the effects of wildfire and prescribed fire on forest hydrology and soil erosion. Pretreatment baseline data on a new study area were obtained, and an additional study site was established to measure and model postburn water-quality responses (*Vose, 02.SRS.B.1, Southern Research Station*).

- Information on the waterflow patterns and geology of sites is critical for assessing risks of postfire erosion and flooding, and selecting postfire treatments that will mitigate these effects. Researchers are working to incorporate these factors into predictive models that

*Post-wildfire peak flood flows are the major threat to watershed resources, cultural resources, and human health and safety after fires are extinguished.*

will provide managers with better support for burned area emergency rehabilitation decisions. Two watersheds with prior data on streamflow at Stermer Ridge (Apache-Sitgreaves National Forest) were reinstrumented to measure post wildfire peak flow floods. Researchers found that peak flow floods on both watersheds were higher than previously measured (1972-1976). Post wildfire peak flood flows are the major threat to watershed resources, cultural resources, and human health and safety after fires are extinguished (*Neary, 01.RMS.B.1, Rocky Mountain Research Station*).

- Stands previously thinned and burned via stand treatments to improve forest health (STIFH) provided the opportunity to investigate postburning forest pathogen conditions in ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) to determine forest pathogen population dynamics and pathogen survivability in stands treated with different fuel reduction treatments. It was found that southwestern dwarf mistletoe (*Arceuthobium vaginatum* ssp. *cryptopodum*) is the most common pathogen in northern Arizona thin and burn STIFH stands. This information will be useful in developing guidelines for postfire vegetation management (*Clancy, 01.RMS.B.4, Rocky Mountain Research Station*).

*Early-spring fire in a pine-hardwood forest ecosystem on the Uhwarrie National Forest, North Carolina.*

## Rehabilitation and Restoration Highlight

### Effectiveness of Postfire Rehabilitation Treatments

**Background:** Each year land management agencies spend millions of dollars on emergency stabilization and rehabilitation treatments to protect downstream resources from increased erosion and flooding after wildfire. However, the effectiveness of many rehabilitation methods has never been tested quantitatively, making it difficult for burned area emergency rehabilitation (BAER) teams to assess realistically the short- and long-term benefits of prescribed treatments relative to their economic and ecological costs.

**Approach:** In fiscal year 2003, researchers established and measured two study sites that test the effectiveness of contour-felled logs, a popular but expensive treatment for reducing postfire runoff and sedimentation, on the Hayman (Pike-San Isabel National Forest, Colorado) and Cannon (Humboldt-Toiyabe National Forest, California) Fires of 2002. They now have six installations measuring the effectiveness of this treatment. The Hayman Fire site also tests two alternative rehabilitation treatments: hydromulch and helimulch (helicopter-applied dry mulch). Analysis to date shows that contour-felled logs may reduce sediment output from watersheds after small or average storms, but they have little effect on erosion or runoff from short-duration, high-intensity rain events. The researchers presented these results at BAER training sessions and professional society meetings attended by land managers and rehabilitation specialists. Preliminary results indicate that the helimulch treatment produced less sediment than the other treatments and the control.

Measurements continued in fiscal year 2003 at the site on the Indian Fire (Prescott National Forest, Arizona), set up in cooperation with the San Dimas Technology and Development Center, where researchers evaluated erosion reduction effectiveness of innovative mulch treatments, relative to hand-spread straw and an untreated control. Felling and chipping all fire-killed trees and spreading compressed straw pellets impregnated with an adhesive substance that ties mulch and soil together, both reduced initial sediment production by 40 to 100 percent relative to untreated plots during the first year, depending on storm intensity. The team established another experimental site in fiscal year 2003 testing alternative rehabilitation treatments following the Williams Fire (Angeles National Forest, California) in several 3- to 5-acre catchments. An aerially applied soil flocculant (polyacrylamide or PAM) had no effect on surface texture, erosion rates, or sediment yield from the winter rains of 2003. Prefabricated wooden check structures (Flow Check™) functioned as designed, trapping sediment in the channels and reducing initial yield from the watersheds. Flocculant-releasing blocks (Floc Logs™) had no apparent effect on movement of sediment once it reached the stream channels.

*Installation of silt fences at the mouth of a treated catchment on the Indian Fire mulch treatment study on the Prescott National Forest.*

**Products:** A color brochure summarizing the first-year results was prepared for managers at the Prescott National Forest and others who have expressed interest. Subsequent data indicate continued effectiveness of these treatments.

**Application:** Over 200 users have been trained in the use of erosion prediction and mitigation effectiveness prediction tools. In 2003, over 18,000 runs were carried out on Forest Service servers predicting soil erosion risks following wildfire and supporting fuel management, with users from over a dozen universities, eight Federal agencies, and every National Forest System region.

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Although the research described here was originally funded as a hazardous-fuels project, the team also is addressing components of postfire rehabilitation as part of its research program.

**Key Partners:**

National Forest System Northern, Rocky Mountain, Intermountain, Pacific Southwest, and Pacific Northwest Regions

## Rehabilitation and Restoration Highlight

### Decision-Support Tools for Fire-Related Erosion

**Background:** Sediment from rapid soil erosion on areas severely burned can damage public drinking water supplies, fish habitats, and downstream structures. Land managers need a way to select and implement effective postfire emergency erosion treatments. Computer modeling tools developed by the Rocky Mountain Research Station can help managers make better decisions about treatments.

**Approach:** Forest Service scientists have made adaptations to the Water Erosion Prediction Project (WEPP) model, originally developed by the Agricultural Research Service National Soil Erosion Laboratory, to make it applicable to forest conditions after fire. These adaptations of the WEPP model use climate, soil, topographic, and vegetation information appropriate to forests to estimate runoff, erosion, and sediment yield from a site. These tools are being made available to managers and field personnel on the World Wide Web. A separate model, the Fire Enhanced Gully Initiation Model (FERGI), addresses effects of specific slope treatments on surface waterflows and streamflow. Fieldwork is continuing to gather data following wildfires and fuel management on sites in California, Colorado, Idaho, Montana, Utah, and Washington to aid in further refinement and validation of all our models.

**Products and Tools:** Tools developed include:

- FSWEPP (http://forest.moscowfsl.wsu.edu/fswepp/) is an Internet-based modeling system used to estimate erosion rates from soils disturbed by fire and to identify what areas have high erosion risk after fire.
- The Erosion Risk Management Tool (ERMiT) model predicts the probability of a given erosion event and annual erosion amount for 5 years following a fire, considering variability in climate, soil, and space. The ERMiT model is particularly useful in predicting the benefits of seeding or mulching on erosion reduction.
- A geographic information system (GIS) interface for the WEPP model (GeoWEPP) aids in postfire predictions of erosion over large, complex landscapes for uses such as protecting sensitive watersheds.
- The FERGI model (http://www.fs.fed.us/rm/boise/) was developed for evaluating the impacts of contour-felled logs, a commonly applied mitigation after wildfire, on surface waterflows and stream channel hydrology. It estimates the probability of runoff events and the probability of gully initiation on hillslopes by using simple information that can be gathered from onsite measurements. Although increased sediment loads reduce fish habitat quality, severe gully-forming events following fire that scour streams and kill and remove fish are of greater concern ecologically. Estimating the degree of risk reduction for such events is important to decisionmaking.

**Application:** The NFP funded 10 workshops in fiscal year 2003 to train natural resource specialists to use the WEPP-based tools. Over 200 practitioners were trained in the past year alone, and more workshops are planned in 2004. Tools developed are being used extensively by all Forest Service regions, many State agencies, consultants, numerous universities, and over a dozen foreign countries. Since May 2003, when it was put on-line, there have been 480 computer runs using ERMiT, mainly for designing erosion control measures after fires in Montana, Idaho, and Arizona. Burned Area Emergency Rehabilitation specialists applied GeoWEPP for the first time in 2003 to a postfire evaluation on a municipal water supply watershed in Idaho. This new tool will be Web-enabled in the future. The FERGI model was first used in 2003 for analysis of three wildfires in Idaho. Information from the model was the deciding factor for not using contour-felled logging over a large area because the marginal decrease in risk of a severe event was too small to warrant the cost. By using additional information about fish ecology provided by NFP-funded research, it was decided that removal of fish passage barriers would be substantially more cost effective for protection of endangered species. The decision resulted in a savings of several million dollars and protected conditions for several populations of a threatened species.

*Researchers from Rocky Mountain Research Station, Boise Aquatic Sciences Laboratory, working on the influence of wildfire on stream fish communities within the perimeter of the 2003 Hot Creek Fire on the Boise National Forest in October 2003.*

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Although one of the teams whose research is described here was funded primarily as a hazardous-fuels project, the team is addressing components of postfire rehabilitation as part of its research program.

**Key Partners:**

Forest Service San Dimas Technology and Development Center (San Dimas, California)

Agricultural Research Service National Soil Erosion Research Laboratory (West Lafayette, Indiana)

Bureau of Land Management National Science and Technology Center (Denver, Colorado)

National Forest System Northern and Intermountain Regions

## Rehabilitation and Restoration Highlight

### Fire and Aquatic Ecosystems Synthesis: A Proceedings

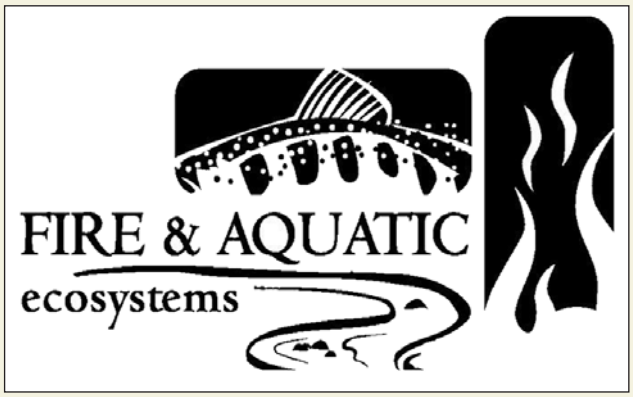
**Background:** The Fire and Aquatic Ecosystems Workshop was held April 22-24, 2002, in Boise, Idaho. The purpose of the workshop was to synthesize new information and current knowledge on the role of fire in, and effects of fire on, aquatic and riparian ecosystems, and to explore potential research areas that will improve understanding of these areas. The goal was to provide a foundation for biologists and managers trying to protect and restore the ecosystems and important processes influenced by fire.

**Approach:** The workshop was arranged around four major themes: fire history, vegetation and postfire management, the effects of fire on physical and watershed-level processes, and the effects of fire on biological processes. Presenters were invited based on their expertise in these areas and the relevance of their work to issues in the management of aquatic ecosystems or the integrated management of terrestrial and aquatic ecosystems.

**Products and Tools:** Fourteen papers including a keynote address by Michael Rains, the primary architect of the NFP, were presented in the workshop. Over 30 leading scientists and managers authored 13 peer-reviewed publications and a formal synthesis of fire management implications from the workshop. These papers appeared in a special issue of *Forest Ecology and Management,* published in June 2003. Information on the workshop with links to related information and publications are available on the Internet: http://www.fs.fed.us/rm/boise/teams/fisheries/fire/firehome.htm.

**Application:** Biologists and managers have used the workshop proceedings extensively. Tracking of Web site activity has documented over 5,000 downloads and requests for workshop papers since January 2003. Some specific comments from a range of users follow:

- "I have used every paper presented in the workshop…I have used the products for BAER training, planning, and implementation, assessing fire effects on threatened and endangered species, emergency consultations, comments on Fire Management Plans, prefire planning, and scientific presentations."
  - Chad Mellison, U.S. Fish and Wildlife Service, Reno, Nevada.
- "I have extensively used the papers from the proceedings. I also forwarded information regarding the workshop proceedings to the National Oceanic and Atmospheric Administration (NOAA) fisheries biologists throughout our northwest and southwest regions, and have had positive feedback about its content and use for Endangered Species Act consultations."
  - Charley Rains, NFP Coordination Team representative for NOAA Fisheries




- "The Boise National Forest has used the newest research from the journal *Forest Ecology and Management* to assess the effects of the Hot Creek Burned Area on the fisheries resource, specifically bull trout. We feel that the research has been key in rationalizing the importance of providing full access to habitat within ecosystems."
  - Thomas J. ("T.J.") Clifford, Boise National Forest Supervisor's Office
- "I thought the special issue of *Forest Ecology and Management* was fabulous… I've already made use of it in classes and at a symposium."
  - Dan Binkley, Director of the Graduate Degree Program in Ecology, and Professor, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University

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**Key Partners:**
University of Idaho Ecohydraulics Research Group
Boise National Forest
Pacific Northwest Research Station Aquatic and Land Interactions Program
National Forest System Forest Service Northern and Intermountain Regions

# Hazardous-Fuels Reduction

*Prescribed fire increased soil bulk density and coarse texture as well as increased and redistributed coarse surface sediment.*

Managing forest and rangeland vegetation and fuels in ways that reduce fire risk to communities and fire damage to ecosystems is a major focus of the National Fire Plan (NFP). Research on hazardous-fuels reduction is helping managers set priorities, determine appropriate treatment regimes, and balance the often complex tradeoffs between the benefits of managing fuels to reduce fire intensity and severity and the possible social, environmental, and ecological impacts of mechanical and prescribed fire treatments.

The following are NFP hazardous-fuels reduction accomplishments for fiscal year 2003:

- Knowledge about the condition of vegetation (fuels) is critical in assessing fire hazards and fire effects; however, managers need tools to help them assess the amount, distribution, and arrangement of fuels in the field. Two photo series volumes (hardwoods with spruce in Alaska and jack pine (*Pinus banksiana*) in the Lake States) were completed that will aid fire and fuels managers in estimating fuel loading and other characteristics for fire planning and fire risk assessment (*Sandberg, 01.PNW.C.1*).

- The objective of the Kings River Experimental Watershed (KREW) study is to quantify the effects of fuel reduction techniques (mechanical thinning and prescribed fire) on small streams. Renovation of the Teakettle Weir will maintain continuity of a valuable streamflow record for small streams that dates from the 1940s. This is a critical control watershed for the KREW study because it is representative of historical conditions for mixed conifer in the southern Sierra Nevada and has never been harvested or significantly influenced by roads. KREW has results that will help to guide managers in selecting fuel reduction treatments best suited for these sensitive zones (*Hunsaker, 01.PSW.C.1, Pacific Southwest Research Station*).

- Researchers are examining various fuel treatments as alternatives to fire in reducing fuel buildups, enhancing soil properties, and improving carbon storage. Through a cooperative agreement with the University of California, Challenge Experimental Forest and Whitmore Forest were instrumented to continuously record soil moisture and temperature fluxes at 20 and 50 centimeters soil depth. Findings will help guide managerial decisions about treating fuels in high-risk zones (*Powers, 01.PSW.C.2, Pacific Southwest Research Station*).

- The effect of fire and fuel reduction treatments on wildlife species is not well understood. A draft study plan was completed for the Plumas-Lassen Administrative Study to assess multiscale effects (stand-landscape) of fuels treatments and wildfire on California spotted owls (*Strix occidentalis occidentalis*) and their habitat within the Herger-Feinstein Quincy Library project area, and to evaluate alternative land management regimes on owls, fuel conditions, wildfire, vegetation, and other response variables. Results will help managers make decisions about fuel reduction alternatives to achieve ecosystem goals while minimizing impacts on key species (*Keane, 01.PSW.C.4, Pacific Southwest Research Station*).

- A book entitled *Restoring Western Ranges and Wildlands* was completed. It will aid specialists in managing existing vegetation and restoring native ecosystems, managing fuels, and reducing the spread of invasive species, and also will provide managers with new tools and plant resources for reestablishing and protecting biological diversity (*Shaw, 01.RMS.C.1, Rocky Mountain Research Station*).

- Scientists investigated the effects of treatments such as thinning, salvage logging, and prescribed fire on soil characteristics and found that hillside erosion from cable logging is so low that silt fences are inappropriate tools to measure erosion rates. This result means that future research using silt fences will be limited to sites that have been disturbed by fire, where erosion rates are higher. Information on the treatment effects will be incorporated into computer models that can be used by managers to assist in fuel management decisions (*Elliot and Page-Dumroese, 01.RMS.C.3, Rocky Mountain Research Station*).

- Researchers are gathering information on the types and methods of fuel reduction alternatives that would be best suited to treating high fuel levels to restore a more natural mix of ecological conditions and reintroduce fire as a management tool. Types of fuels management in western ecosystems are described in the *Proceedings of the Fire, Fuels Treatment and Ecological Restoration* workshop, funded by both the Joint Fire Science Program and the NFP. Nearly 300 managers, scientists, and policymakers attended the 2002 workshop in Fort Collins, Colorado, and attested to the value this report will have for fuels management and ecological restoration in the Western United States (*Joyce, 01.RMS.C.4, Rocky Mountain Research Station*).

- Prescribed burning is cost-effective but frequently off limits because of safety or liability issues and smoke regulations. New fuel management strategies require methods to characterize the extent and spatial distribution of the wildland-urban interface. An investigation is being done to define the characteristics of the wildland-urban interface in the South and develop integrated systems to manage fuel loads. An outcome from this research will be a decision-support system to help users make cost-effective decisions on fuel treatments with knowledge of the nonmonetary environmental effects of the treatment (*Stanturf, 01.SRS.C.4, Southern Research Station*).

- Researchers investigated the effectiveness of a treatment that combines prescribed fire with herbicide treatments to reduce fuel buildup. The first study that used this treatment was successfully completed by Florida Department of Forestry and the St. Johns River Water Management District personnel. Results from this study will help landowners to accurately weigh the costs and benefits of prescribed fire as a forest management tool, balancing wildfire prevention, reduced treatment costs, and potential impacts on timber production (*O'Brien, 01.SRS.C.5, Southern Research Station*).

- Researchers examined multiple components of fuels as they relate to fire hazard for landowners in the wildland-urban interface. Specific projects address interface landscape characteristics and fire risk, flammability ratings of southern fuels, landowner risk assessment procedures, and fuel management options for landowners. An extension fact sheet was released entitled "Fire in the Wildland-Urban Interface: Understanding Fire Behavior" (*Roussopoulos, 01.SRS.A.3, Southern Research Station*).

- The cost of removing small-diameter trees can be more than the value of the wood, but if cost-effective methods for removal and markets for use could be found, forest management costs could be offset. For the strategic assessment of forest biomass and fuel reduction treatments in the West, potential revenue from products was compared to costs. In virtually all areas, sale of some larger diameter trees (greater than 7 inches diameter at breast height [d.b.h.]) for higher value products was needed to cover costs of harvesting. Sale for fuel wood was not sufficient to cover costs. Evaluations indicate the need to either subsidize the cost for thinnings or find higher value uses for timber greater than 7 inches d.b.h. (*Skog, 02.FPL.C.1, Forest Products Laboratory*).

- Little is known about animal and plant responses to wildfire, fire exclusion, or fuels management treatments designed to mimic presettlement conditions. We developed and applied methods to monitor wildlife populations and habitats following wildfire and fuels reduction treatments. This information will help land managers assess cumulative effects and evaluate ecological tradeoffs when considering options for treating and managing fuels (*Block, 02.RMS.C.2, Rocky Mountain Research Station*).

- Researchers worked to develop marketable products from forest undergrowth and underutilized timber to encourage its harvest and use. Laminated structural I-Beams were made from small-diameter curved and unmerchantable trees at a Wyoming sawmill. Structural evaluations show that a value-added product could be made from suppressed-growth unmerchantable trees. The resulting laminated beams had good strength properties, similar to those from larger diameter trees. This information will provide a sawmill or stud mill with engineering data to verify the potential for using low-value, small-diameter trees to produce a value-added structural product (*Hunt, 01.FPL.C.2, Forest Products Laboratory*).

- Previously oak-dominated forests are shifting to maple dominance owing to fire exclusion over many years. Prescribed fire and thinning treatments may restore oak dominance, but there is little information on fuels, fire behavior, and fire weather in the region to guide these efforts. An interdisciplinary team of scientists conducted experimental burns and theoretical work to study how trees (oak and hickory forests) are killed in forest fires.

Managers can use software based on a physically based tree mortality model produced from this study to evaluate restoration options for these fire-dependent ecosystems (*Dickinson, 01.NES.C.1, Northeastern Research Station*).

- Researchers gathered information to help managers identify areas of high fire risk, and to develop management options to reduce future fuel loads. Scientists developed county-level estimates of fine, medium, and large down deadwood biomass and live tree biomass for the Eastern United States. They also developed a prototype map at 30-meters resolution depicting wildfire risk in the wildland-urban interface based on land use change and forest patch characteristic data sets (*McNulty, 01.SRS.C.1, Southern Research Station*).

- To understand the physical effects of prescribed burning on soil processes affecting runoff and erosion in semiarid environments, researchers completed soil data collection for a prescribed burn conducted on the San Dimas Experimental Forest. The researchers determined that prescribed fire increased soil bulk density and coarse texture as well as increased and redistributed coarse surface sediment. Prescribed fire can be useful to managers to economically manage sediment in chaparral systems (*Hubbert and O'Dea, 01.PSW.C.3, Pacific Southwest Research Station*).

- Lodgepole pine (*Pinus contorta* Dougl. ex Loud.) is the fourth most extensive timber type west of the Mississippi River and the third most extensive in the Rocky Mountains. Currently, many lodgepole pine stands are in late-successional stages containing high fuel loading; these stands are at high risk of catastrophic fires, such as occurred in 2000 and 2003. Scientists from several disciplines working on the Tenderfoot Creek Experimental Forest are exploring the ecological and biological effects of thinning and prescribed fire in lodgepole pine stands through silvicultural prescriptions that reduce forest fuels, restore healthy stand structure, and maintain species composition. This research will result in recommendations on silvicultural options including fuel treatments for reducing fuel loading, improving stand health, and maintaining regeneration potential; options for hydrologic and wildlife considerations; and prescriptions for improving residual tree growth (*McCaughey, 01.RMS.C.6, Rocky Mountain Research Station*).

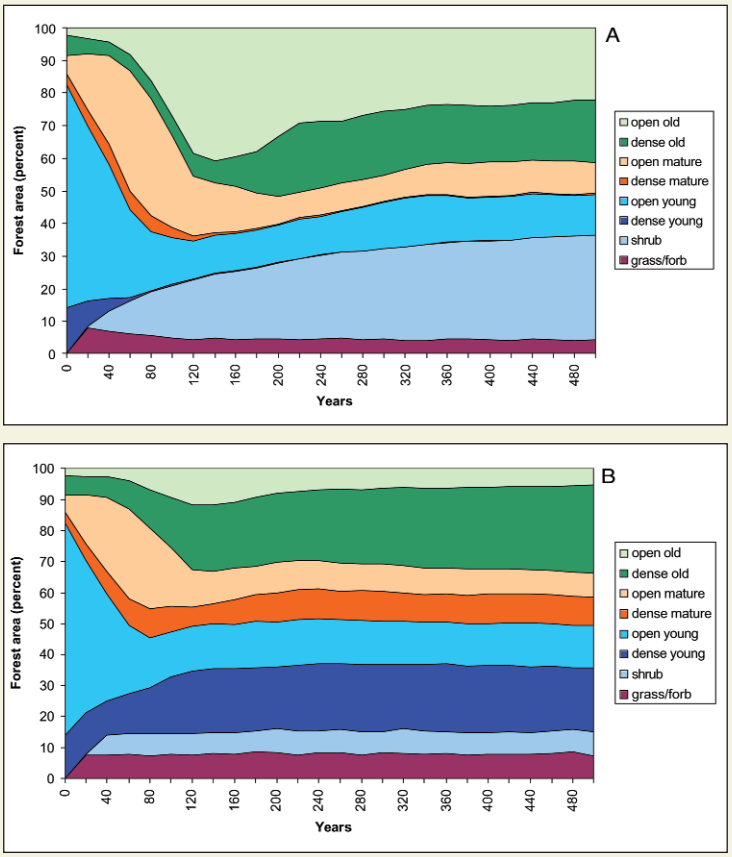
- Reducing fuel buildups, with or without prescribed fire, may adversely impact the environment through increased erosion and runoff, reduction in stored carbon and forest health, or damage to remaining vegetation. There is little integrated information on the impacts of biomass reduction operations on soil, water, and forest health. Scientists at the Rocky Mountain Research Station found that engineered wood straw is as effective as wheat straw at reducing soil erosion. In areas where production of this material is economical, it may replace wheat straw on postfire and other disturbed sites for erosion mitigation. This information will help managers in assessing the impacts and selecting among the array of fuel-reduction alternatives available to them (*Elliot, 02.RMS.C.1, Rocky Mountain Research Station*).

## Hazardous-Fuels Highlight

### Financial Analysis and Processing Options for Hazardous Fuels

**Background:** The Blue Mountains in northeastern Oregon have presented many challenges to forest managers during the past two decades. In the 1980s and 1990s, a severe outbreak of spruce budworms (*Choristoneura fumiferana* [Lepidoptera: Tortricidae]) caused extensive mortality, opening up stands and greatly increasing fuel loadings. Lower stand densities resulted in extensive conifer regeneration, which was encouraged in part by grazing by cattle, deer, and elk. The high fuel loadings and increasing stand densities of young conifers heightened concerns about fire hazard over extensive areas of the Blue Mountains. Partially in response to these conditions, the Forest Service established the Blue Mountains Demonstration Project to "accelerate ecosystem restoration in a manner that benefits local communities and unites land managers and scientists in cooperative efforts."

**Approach:** Researchers worked through the Blue Mountains Demonstration Project and other National Forest System staff to develop techniques that would help them to view management actions from the standpoint of the larger landscape and to understand the effectiveness of Federal land management decisions in mixed land management practices. In part, this involves stepping down analyses from broad regional reviews to the subbasin scale to specific projects.




*Upper Grande Ronde study area, potentially forested land, (A) low grazing, and (B) high-moderate grazing background fire, 500 years.*

**Application:** Over the past 2 years, project scientists and professionals have participated in the Blue Mountains Vegetation Assessment (an effort by the Blue Mountains Demonstration Project and the Oregon Department of Forestry to determine whether timber production could support fire-hazard reduction in northeastern Oregon) and the Mount Emily Project (an NFP-supported fuels reduction project by the La Grande Ranger District in the wildland-urban interface near La Grande, Oregon) to provide examples of how managers can use the most up-to-date science and modeling tools in analyses to support decisions about reducing fire hazard at both a landscape scale and in site-specific instances. Outcomes of these analyses are helping decisionmakers and managers, from the three forest supervisors to district-level specialists, to understand the possibilities and challenges associated with implementing current natural resource management policy. For example, the mapping exercise conducted by the three national forests for the Blue Mountains Vegetation Assessment helped decisionmakers realize the importance of various land allocations in restricting their ability to array landscape-level fuel treatments in an efficient and effective manner. Our financial and wood utilization analyses helped them to understand the challenges associated with finding areas where treatments could "pay for themselves" and at the same time reduce fire threat.

At the subbasin (500,000- to 1-million-acre) scale, the analyses are helping managers to recognize some of the difficulties associated with accomplishing reductions in fire threat over the long term. For example, deer and elk are a part of the ecosystem in northeastern Oregon, and cattle are a political fact of life. The analyses suggest that ungulate herbivory has an important effect on both the structural characteristics and species composition of stands in the Blue Mountains. This information suggests that policies directed toward timing of management activities and controlling numbers and distribution of ungulate herbivores could influence stand structure and composition over large parts of the Blue Mountains. From an economic standpoint, this points to the need for a continuing program to control regeneration across the landscape, which probably means

## Hazardous-Fuels Highlight

a sustained program of maintenance burning and mechanical fuels treatments, such as mastication, that have negative net financial revenues.

The analyses at the project level support some of these same findings. Projections of stand structure and fire behavior made for the Mount Emily fuels reduction project indicate a need to control conifer regeneration after treatments designed to reduce crown bulk density (an indicator of crown fire potential). This analysis also shows that in a wildland-urban interface with mixed ownerships, it is not enough to only treat the lands administrated by the Forest Service; involvement of all landowners in efforts to reduce fire hazard will be much more effective. This finding does not address the social aspects of "getting people involved," rather it is a technical finding that relates to the distribution and timing of treatments across the landscape and the need to alter structural conditions where it will do the most good to change fire behavior.

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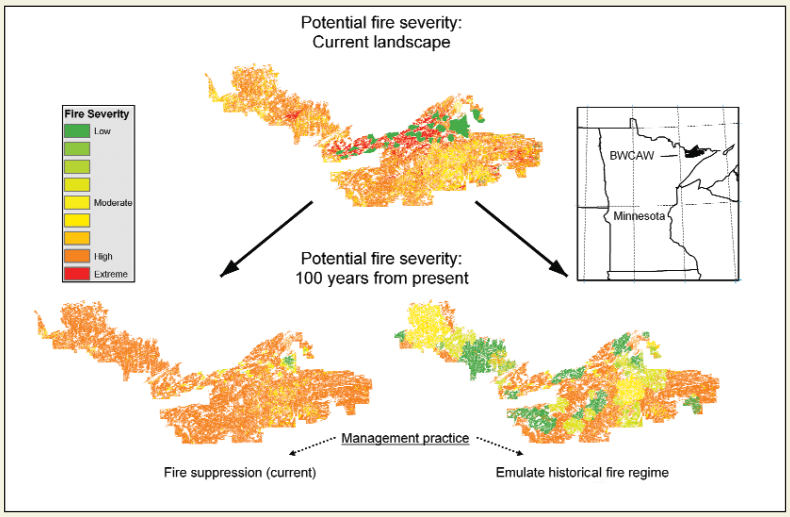
**Key Partners:**
The Blue Mountains Demo
The Umatilla National Forest
The Wallowa-Whitman National Forest
The Malheur National Forest
Pacific Northwest Region Planning
Boise Corporation
Southwestern Region Natural Resources and State and Private Forestry

## Hazardous-Fuels Highlight

### Predicting Landscape-Scale Fire Risk

**Background:** The spatial distributions of fuels and forest types affect the spread of fires and the severity with which they burn. As a result, fire risk in a given location (for example, a community or a home) depends not only on the condition of the adjacent forest but on the condition of the forests in a much larger landscape. The development of effective and efficient fire-risk reduction strategies requires tools that will predict the response of forests, fuels, and fire risk to landscape-level processes, including forest management and natural disturbances.




*Projecting the effect of fire and fuels management on potential fire severity in the Boundary Waters Canoe Area Wilderness, Minnesota.*

**Approach:** Working with resource managers, Forest Service and university researchers are using LANDIS (a landscape simulation model) to simulate the effects of current and proposed forest management strategies on fire risk and fuel loadings. Model results for the Superior National Forest, for instance, show that continued fire suppression in the Boundary Waters Canoe Area Wilderness will result in increased fire risk and substantial changes in forest composition, while the introduction of prescribed fire will reduce fuel loads and maintain native fire-adapted species. Similar results were seen in the fire-adapted oak forests on the Mark Twain National Forest, where model results show that the rate of prescribed fire use significantly affects the forest's susceptibility to wildfire—as prescribed fire use increases, the predicted average size, intensity, and frequency of wildfire decreases. On the Chequamegon-Nicolet National Forest, however, none of the eight alternative forest management strategies proposed for a forest plan revision have unintended consequences for landscape-level fire risk, although activities that increase the abundance of conifers (timber harvest and blowdowns) also can increase fire risk in some local areas.

**Products and Tools:** Scientists at the North Central Research Station have been working with partners at the Universities of Wisconsin-Madison and Missouri-Columbia to develop a sophisticated forest landscape model that simulates forest responses to these interacting drivers of forest change. LANDIS simulates forest dynamics across hundreds of thousands of acres, over timespans ranging from decades to centuries.

**Application:** As part of the collaborations developed through these NFP projects, the results from this work have been applied in the forest plan revision process and form the basis for a large effort in which representatives from State, Federal, and nonprofit landowners are evaluating the cumulative effects of forest management on forest composition and fuel loading in a large, mixed-ownership landscape. In addition, NFP is funding ongoing efforts to improve the capabilities of the LANDIS model. In January 2004, a new version of LANDIS will allow the important relationships between forest disease and insect outbreaks, fuel loadings, and fire risk to be simulated, and new, more powerful fire ignition and spread algorithms will improve the modeling of these complex phenomena. These capabilities will be applied to help managers develop fire management plans on the Chequamegon-Nicolet, Superior, and Huron-Manistee National Forests. The LANDIS model has great potential to be applied in many different ecosystems throughout the country where vegetation management and natural disturbances interact to affect the risk of wildfire.

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**Key Partners:**
University of Wisconsin, Madison
University of Missouri, Columbia

## Hazardous-Fuels Highlight

### The Relationship Between Forest Structure and Fire Severity

**Background:** Large wildfires can be very destructive but are also large-scale experiments that provide scientists opportunities to do research at a scale they could neither afford to nor would they be allowed to conduct. There is limited information available to determine forest structure (vertical and horizontal density) on fire severity during wildfires. Fire severity can provide an indication of forest structure, which in turn can influence fire behavior. Fire severity also can be used to predict the recovery of a particular forest stand after it is burned by a wildfire.

**Approach:** Researchers hypothesize that (1) wildfire severity is altered by forest structure and (2) vegetation recovery differs with fire severity. To address hypothesis 1, scientists are conducting a retrospective study to evaluate the relation between forest structure and fire severity. A total of 559 stands have been randomly selected and sampled in 21 large wildfires that occurred during 2000-2002 in Montana, Colorado, and eastern Oregon. To address hypothesis 2, a subset of these plots in Montana and Oregon is being used to quantify vegetation recovery at 1, 3, 5, 10, and 15 years after wildfire.

Preliminary results show that fire severity is best described in terms of litter cover, mineral soil exposure, and tree crown and bole scorch. In addition, forest structure affects fire severity. Important stand structure predictors of fire severity are tree density, average stand height, crown base height, and tree diameter. For example, (1) stands less than 26 feet tall have a 62-percent probability of a low-severity fire, (2) stands with crown base heights higher than 20 feet tended to have lower fire severity than stands with crowns less than 20 feet above the ground, and (3) stands with lower densities or smaller average tree size had lower fire severities than denser stands or larger trees.

**Products and Tools:** The retrospective fire-severity study will provide information on the relationships between forest structure and wildfire severity by displaying empirical probability distributions associated with fire severity and forest structure, key structural characteristics related to fire severity, and thresholds in structural characteristics. From the vegetation recovery study, scientists will construct predictive models of vegetation development based on prefire stand structure, postfire stand structure, and fire severity. Both the fire severity and vegetation recovery results will be incorporated into the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS). The FFE-FVS predicts fire behavior, fire effects, snag dynamics, and woody fuel decomposition over time, with and without management. In turn, FFE-FVS will be linked to models that predict postfire soil erosion. Results also will be published in various outlets, and other technology transfer will take place through presentations and consultations.

*This hillside shows part of the 2002 Flagtale Fire in eastern Oregon. As shown in this photograph the fire burned from the left to the right. A high-density stand on the left was killed by a crown fire (black crowns). In the middle, the fire entered a thinned area and changed to an intense surface (brown crowns). The right portion of the photograph shows where the fire intensity decreased, and only a few trees were killed (green crowns) from a low-intensity surface fire.*

**Application:** Land managers can use this information to design treatments that will reduce wildfire severity at the stand and landscape levels of planning. The information on vegetation recovery can be used to prioritize erosion control, predict stream hydrology, and forecast browse production.

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**Key Partners:**
National Forest System
Forest Inventory and Analysis

## Hazardous-Fuels Highlight

### Hazardous-Fuels Reduction Through Harvesting Underutilized Trees and Forest Undergrowth and Producing Three-Dimensional Structural Products

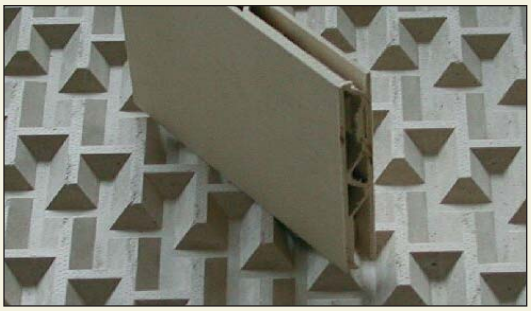
**Background:** Many forests in the Western United States have residual material from logging or thinning operations that has little or no value because of the high costs associated with removing and processing these materials. To provide incentive to market a product and provide the needed revenue to cover the associated costs, economical processes and value-added products that would provide sufficient performance/cost advantages over existing products need to be developed.

**Approach:** At the Forest Products Laboratory in Madison, Wisconsin, research scientists are (1) developing an economical process to reduce this low-grade material into a homogeneous bondable fiber mixture, and (2) developing a process to engineer value-added three-dimensional structural fiberboard with performance properties. Such a product could be used in the production of many products such as pallets, bulk bins, heavy duty boxes, shipping containers, packaging supports, wall panels, roof panels, cement forms, partitions, displays, reels, desks, caskets, shelves, tables, and doors.

The material-processing research uses existing industrial wet-processing equipment to reduce the material into a homogeneous fibrous slurry. The fiberizing process is similar to that used in pulping for paper, but the requirements for pulp quality are significantly reduced. The fiberization process includes bark in the mixture, whereas pulp for paper requires debarked clean material. The process also uses very few, if any, chemicals in the pulping process and requires less refining to produce a useable fibrous pulp. The research is developing a technology to form a three-dimensional fiberboard with predictable fiber distribution, shape, and properties.

The formed fiber mat is pressed by using heat and pressure to bond the fibers together with or without resin. Once dry, the final properties of the bonded fibrous material are equal or superior to commercial hardboard, and scientists are able to design for a range of specific performance requirements for packaging to structural uses. To date, scientists have used lodgepole pine treetop material including the bark, fiberized it, designed specific three-dimensional molds, and are making three-dimensional structural panels for testing. The scientists are finalizing the engineering equations and computer modeling techniques that will be used to verify the predicted properties with those from the tested structural panels.

**Products and Tools:** The outcome of this research will be fiber-processing information and three-dimensional engineering and modeling techniques that a small- to medium-size company could use to determine potential economic costs and returns on their investment for a given product need.



*Engineered cores can have complicated geometries to produce a laminated structural panel product for specific performance requirements. The panel shown is about three-fourths of an inch thick.*

*Engineered structural panels can be made by using simple uniaxial core structures to provide efficient structural panels. The panel shown is approximately 1-½ inches thick.*

**Application:** This product also will provide improved forest management opportunities to fully utilize the fiber resource off the forests. The process can be tailored to use most any logging residues or thinning material. The proposed technology, if it were adopted, would clear land for much needed rural development and would significantly reduce the cost to the Federal Government for fire mitigation. The economic feasibility of constructing panels by using this process from these materials will be developed.

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**Key Partners:**
Bighorn National Forest—Tree Tops for Fiber
Wyoming State Forest—Tree Tops for Fiber
Genesis Laboratory, Batavia, Illinois
Crescent Technology, LLC, Madison, Wisconsin

## Hazardous-Fuels Highlight

### Fuel Reduction and Forest Restoration Strategies That Sustain Key Habitats, Species, and Ecological Processes in Fire-Prone Ecosystems in the Interior Northwest

**Background:** It is relatively well known that past forest management practices have altered fire regimes, but the effects of management treatments to alleviate this problem on key habitats and species are not well understood. Concerns about key species in mature and old forests, such as the northern spotted owls (*Strix occidentalis caurina*), have led to controversy over large-scale fuel management plans. Although the concerns are valid, management also might consider how to increase long-term persistence of old forest while restoring open ponderosa pine (*Pinus ponderosa*) habitat for other sensitive or keystone species. Another consideration is how to design stand- and landscape-level fuel and fire management strategies to maintain or restore both sets of key habitats and species.

**Needs:** Information is needed to determine the effects of treatment alternatives, including no treatment, on key ecological processes and elements of biodiversity, particularly late-successional forests, keystone species such as woodpeckers (*Dendrocopus*), and threatened and endangered species. Management needs to restore some habitats and maintain others, but the uncertain impacts of altered fire, insect, and pathogen disturbance regimes make that task risky.

**Approach:** There are two components of this program: (1) research to design appropriate treatments at stand and landscape scales; and (2) the development and testing of those treatments with managers in an operational, but experimental, adaptive management approach.

**Products:** A key product is the organizational change in thinking among scientists and managers when they cooperate in gaining reliable knowledge through our adaptive management projects. A 5-year cooperative agreement with University of Washington scientists is focused on understory plant species responses to fire and thinning. Information from two adaptive management experiments and a number of other research projects on key species and processes (e.g., snag, bird, and mammal ecology and northern spotted owl habitat selection) and their management will be demonstrated through a series of publications over the next several years. Several local workshops have been held. Prototype decision-support systems are being designed.

**Tools and Applications:** Research has provided reliable information to design projects and do credible National Environmental Policy Act analysis, and for scientists to better understand the impacts of management on ecosystems. The Okanogan, Wenatchee, and Colville National Forests are the first forests in the Pacific Northwest Region of the Forest Service to revise their forest plan; work on these forests will contribute to their groundbreaking process. Decision-support systems will help managers to understand complex research for planning. Generally, the work will contribute substantially to the knowledge base for scientific management of fire-prone ponderosa pine and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests throughout the West.

*Prescribed fire used for fuel reduction is a critical process that may create or destroy snags and defective trees and that changes the pattern of the remaining forest around snags in ways that can influence the nonexcavating species that depend on them to create nesting cavities.*

**Implementation Example:** On the Okanogan National Forest, the results of the work are being used to help design sound fuel and fire management on 350,000+ acres of dry forest. Research is a partner with the forests in three "adaptive management" projects on 5,000+ acres, including two that are part of regional or national "metaexperiment" research networks (28 sites total), that examine in part or in whole the effects of prescribed fire or fire surrogate (thinning) treatments on ecosystem pattern (e.g., plants, animals, fuels, and soils) and processes (fire, insects, and disease). Treatments in both studies are scheduled for spring 2004.

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**Key Partners:**
Colvillle, Okanogan, and Wenatchee National Forests
Rocky Mountain Research Station
University of Washington
Washington Department of Fish and Wildlife
U.S. Fish and Wildlife Service
National Council for Air and Stream Improvement, Inc.
U.S. Geological Survey, Fort Collins Science Center
The Nature Conservancy
Washington Department of Natural Resources
Longview Fiber Company
Plum Creek Timber Company

## Hazardous-Fuels Highlight

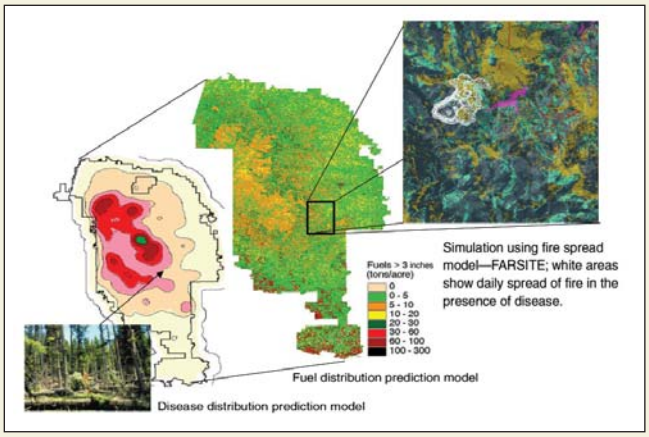
### Use of Remote Sensing To Examine Disease Effects of Fuel Patterns

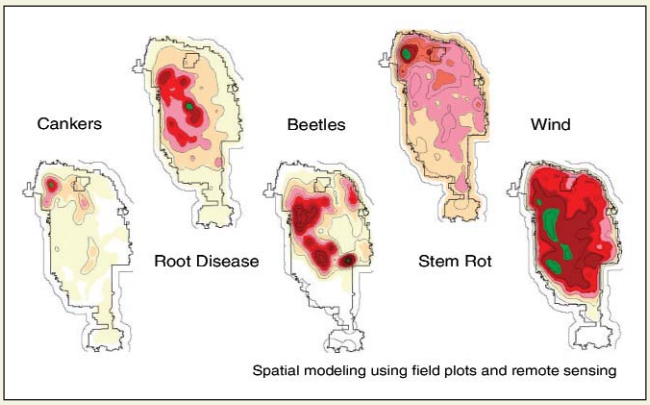
**Background:** Tree diseases are among the least understood and possibly the most underestimated causes of increased dead fuel loads in forest stands and landscapes. Manipulating forest diseases could be a useful long-term strategy for managing fire risk, but there are few integrated models available to characterize and predict the influence of disease on fire behavior and to guide disease management activities.

Forest pathologists and fire managers need tools that enhance collaboration and communication in decisionmaking. A landscape-scale model for spatial management of diseases is needed that integrates fuel and pathogen probability distributions with predictive fire-spread models. To be a practical tool, this model needs to be based on remote sensing coupled to data from ground plots and spatial analyses. These models would be useful in selecting and prioritizing prescriptive disease management activities aimed at controlling fire risks and in determining where to do them.

**Approach:** This study involved four phases: (1) Landsat TM imagery combined with field assessments and spatial analyses were used to develop landscape-scale predictive spatial models for several types of fuels and to generate the probable distributions of pathogens and other types of disturbances. (2) These models were then integrated into an existing fire-behavior model to predict the influence of different diseases and their locations on fire spread and impact. (3) Based on simulations from these models, methods of determining the relative importance of different diseases compared to other disturbances across the landscape were developed to help prioritize management options. (4) Various methods of collaborating, communicating, and integrating the technologies developed through this study into the management decisionmaking process are being examined.

**Products:** (1) Predictive spatial models showing varying conditions of various fuel types, different pathogens, and other kinds of disturbances within stands across the entire forest were generated. (2) These models were integrated into the fire-behavior model, FARSITE, and used to run simulations. (3) A method of estimating the relative importance of diseases compared to other types of disturbances showed that root diseases caused 32 percent of the total fuel load, bark beetles (*Hylesinus oleiperda* Fabricus) 21 percent, lightning damage 11 percent, wind damage 10 percent, canker diseases 10 percent, and others in a ponderosa (*Pinus*) stand under endemic conditions. (4) The integrated models were transferred to managers on a national forest for beta testing, which should improve the chances that the final product will better match users' needs.




*Probability distribution models of fuel-generating diseases and other disturbance agents in the Black Hills National Forest.*

**Application:** Tools developed offer a practical way to monitor fuel abundance and distribution from substand to landscape scales and to predict how fuel distribution and fire spread are influenced by changing disease dynamics and the application of different disease management activities. Managers could use these models to develop prescriptions for mediating fire risk by managing spatial patterns of fuel-generating tree diseases and other types of disturbances.

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**Key Partners:**
Colorado State University
Yale University
U.S. Geological Survey
National Forest System
Southern Ute Tribe
Mesa Verde National Park

## Hazardous-Fuels Highlight

### Quantifying the Tradeoffs of Fire and Fuels Management Options for Longleaf and Slash Pines in the South

*Progression of thin and burn treatment from initial conditions (upper left) to thinning operation, to postthin conditions, to prescribed burn treatment, to immediate postburn, to one growing season following burn.*

**Background:** The longleaf pine (*Pinus palustris*) ecosystem of the South, which evolved with and is adapted to frequent low-intensity fires, is at risk of uncharacteristically severe wildfires that threaten people's lives and property and the health of this endangered forest community. Widespread fuel reduction treatments are needed to restore ecological integrity and reduce the risk of destructive wildfires. Of particular concern in the South are the rapidly growing urban-wildland interfaces of the Coastal Plains. Prescribed burning has been used for decades in the Coastal Plain to reduce fuel loads but is now under regulatory pressure. At issue are adverse air-quality and transportation safety impacts of smoke from prescribed burning and the potential for property losses if these burns escape into the wildland-urban interface. Alternative fuel reduction treatments are attractive, but the appropriate balance among cuttings, mechanical fuel treatments, herbicides, and prescribed fire is unclear.

**Approach:** This research is comparing effects of herbicide, prescribed burn, mechanical and combination treatments on fuels and ecosystem characteristics. Numerous questions are being addressed on operational-sized treatment units across broad disciplinary areas. Areas of study include vegetation, fuels, fire behavior, ecosystem structure, soil compaction, nutrient cycling, forest floor dynamics, mammals, herpetofauna, avifauna, entomology, pathology, treatment costs, and utilization economics. This study is being conducted in south Alabama at the Solon Dixon Forestry and Education Center operated by Auburn University.

**Products:** All combinations of treatment units of herbicide and prescribed-burn treatment were successfully burned on schedule this past season without incident, demonstrating that it is possible to use prescribed burning in a short time interval after other fuel reduction treatments without undue risk of fire escape or tree mortality. Early results have shown that hazardous fuels can be reduced without significant overstory damage by using a combination of thinning and prescribed burning via commercial timber sales that generate sufficient income to more than cover the cost of burning. These results have application to an estimated 10 million acres in the region, where they will be used to guide investment of scarce treatment funds to give society the greatest reduction in wildfire risk while improving ecosystem health of the imperiled longleaf pine ecosystem and its host of threatened and endangered species.

**Products and Tools:** The results described above have been presented at workshops and conferences across the South. Information generated by this research will be used to create a decision matrix to provide resource managers with costs and benefits based on ecological, economic, and social consequences of alternative fuel reduction practices.

**Application:** During this past year, 200 persons viewed the study sites including managers from U.S. Fish and Wildlife Service and private industry, private landowner groups, and students from grade school to the university level. Because of the demonstrated success of the treatment as an effective means of reducing wildfire hazard, improving ecosystem health, and maintaining long-term sustainability, the managers of the Solon Dixon Forestry and Education Center plan to apply fuel reduction treatments to a number of their longleaf stands.

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**Key Partner:**
Solon Dixon Forestry and Education Center, Auburn University

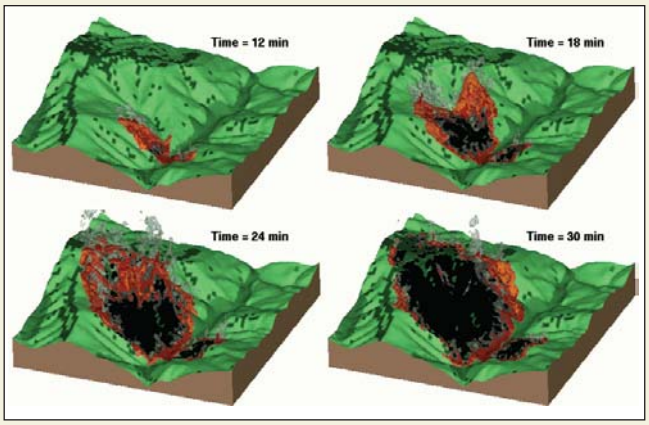
## Hazardous-Fuels Highlight

### Developing and Validating a Coupled Atmospheric and Physics-Based Wildfire Behavior Model for Use in the Southwest

**Background:** Improved predictive models of fire behavior are needed to support forest fuels reduction activities, wildfire mitigation efforts, planning for prescribed burns, evaluating potential fire behavior, and assessment of postfire environmental effects. Advancements in wildfire models can dramatically increase the ability to anticipate and respond to fires in situations composed of a variety of live and dead fuels with complex topography and fire-influenced winds. In addition, there is an increasing need to link fire behavior models to postfire effects and mitigation treatments that affect soil erosion, chemistry, productivity, and revegetation. Although existing operational models have been demonstrated to accurately describe some time-integrated results of long-duration fires, these models are not designed for application in the presence of rapidly changing weather (wind) or complex variations in physical environment (such as topography or nonhomogeneous fuels) created by various silvicultural treatments to reduce forest fuels and restore forest health.

**Approach:** The research approach involves further development, validation, and refinement of a physical-process wildfire model, FIRETEC, originally developed at Los Alamos National Laboratory to include representations of combustion, wind interactions with fuels, heat transfer mechanisms, and fire-influenced atmospheric flows. Collaborators are working to provide real-time data from prescribed burns on operational fuels management research areas that are part of a national study of the consequences of fire and fire surrogate treatments supported in part by the Joint Fire Science Program. This effort is a collaboration of the Rocky Mountain Research Station; U.S. Department of Energy, Los Alamos National Laboratory; Pacific Southwest Research Station, Riverside Forest Fire Laboratory; Rocky Mountain Research Station, Missoula Fire Sciences Laboratory; New Mexico State University Department of Mechanical Engineering; and Northern Arizona University School of Forestry.

**Products and Tools:** The FIRETEC model is the first physics-based, three-dimensional model designed to simulate the constantly changing, interactive relationship between fire and its environment. The model includes representation of the coupled interactions between fire, fuels, atmosphere, and topography on varying scales ranging from within forest stands to a landscape scale. The FIRETEC model combines physics models that represent combustion, heat transfer, aerodynamic drag, and turbulence with a computational fluid-dynamics model that represents airflow and adjustments to terrain, different types of vegetation fuels, and the fire itself. Unlike empirically based models in current operational use, FIRETEC simulates the dynamic processes that occur within a fire and the way those processes relate to and alter each other. The level of resolution embodied in the model allows research and development in wildfire mitigation strategies to be conducted at a level of detail in time and space not available in existing operational models.




*Simulation of the Corral Canyon portion of the Calabasas Fire in 1996 near Malibu, California. Images are 12, 18, 24, and 30 minutes after spot ignition at the bottom of the canyon. Firefighters that had been dispatched to the top of the ridge, shown in the upper left of the image, were overcome by the fire and were injured.*

**Application:** Physical-process models that intimately couple topography-influenced atmospheric flows with physics-based fire models have demonstrated sensitivity to these more complex conditions and provide more accurate results over short periods. Owing to computational complexity and fine-scale resolution, these process models are not currently capable of being implemented in real-time situations. However, with further validation and development from ongoing field experiments, these models can be used as training, planning, and risk assessment tools. More importantly, these models provide a critically needed tool for further development of simpler, computationally efficient wildfire behavior models for operational purposes. This effort also facilitates regional and national collaboration with scientists and managers in other disciplines interested in using fire-behavior models to assess expected effects on vegetation, habitat, soils, and watershed condition. The collaborative development of the FIRETEC wildfire behavior model recently received an "R&D 100 Award" for innovation and potential service to society in a national competition sponsored by R&D Magazine.

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**Key Partners:**
Los Alamos National Laboratory
Coronado National Forest
Lincoln National Forest
Coconino National Forest

# Community Assistance

Fuel treatments cannot protect communities from wildfire unless the communities themselves are fire safe. To protect communities from wildland fire, community leaders and residents must understand and act on the need for structures and their immediate surroundings to be modified in a way that reduces fire risk. Fire research (National Fire Plan [NFP]) is improving our understanding of community attitudes and beliefs and developing new approaches to working in partnership with communities to enhance preparedness and decrease the negative social and economic impacts from wildland fires.

*Where prescribed burning is common, respondents were more likely to approve of prescribed fire, trust a government agency to engage in prescribed burns, and think prescribed fire restores natural conditions and improves wildlife habitat.*

The following are NFP community assistance accomplishments for fiscal year 2003:

- Researchers examined the aesthetic and social acceptability of various forest management treatments. Where prescribed burning is common, respondents were more likely to approve of prescribed fire, trust a government agency to engage in prescribed burns, and think prescribed fire restores natural conditions and improves wildlife habitat. This information can help managers in creating effective strategies for working with the public and developing fuel reduction and restoration activities that are locally acceptable (*Dwyer, 01.NCS.D.1, North Central Research Station*).

- Researchers gathered information from communities that have been successful in disaster preparedness to identify what factors are critical to success and develop models of community cooperation and partnerships. Fifteen studies were completed that focused on community decisions and actions related to wildfire preparedness. Several elements were identified as being critical to developing community preparedness for wildfire: a stable local fire department, leaders and community members who can think "outside the box," community members who have knowledge or skills that transfer to wildfire preparedness, a local champion or leader for wildfire preparedness, networks for collaboration, and governmental involvement (*Jakes, 01.NCS.D.2, North Central Research Station*).

- Researchers developed a set of alternative landscape designs that will enable homeowners to meet their personal landscape needs while at the same time increasing fire safety. FIREWISE Version 1, a Web-based program, allows homeowners and agency staff to visualize how planting, pruning, and removal of vegetation influence fire hazard to structures. In so doing, it can help residents take responsibility for protecting their homes from fire (*McPherson, 01.PSW.D.2, Pacific Southwest Research Station*).

- Scientists are studying the effects of information on people's perceptions and choices related to fire management techniques with the goal of improving two-way communication between the public and fire management agencies in reducing fire hazard. Two workshops were conducted with members of the Ridgewood Homeowners Association (near the Manitou Experimental Forest, Colorado Springs, Colorado) to discuss risk perception and fire and fuels management preferences after the Hayman Fire. An annotated bibliography has been prepared on the risk perception and risk communication literature. This literature will assist land managers with designing recommendations for communicating

fire and fuels management strategies and implementing successful, socially acceptable, fire and fuels management policies and programs (*Kent, 01.RMS.D.1, Rocky Mountain Research Station*).

*Managers may need to provide clear messages to visitors about fire management with explanations of why no fires are allowed, why there is decreased air quality, and why there may be traffic delays.*

- Catastrophic wildfires take a large economic toll on communities, including property losses, decreased tourism, and even changes in the long-term structure of the local economy. A decision-process framework was developed that illustrates the importance of social measures in developing effective responses to wildfire threats. Findings indicate that an effective community response to wildfire means that a community works through all stages of the decision process with appropriate social and structural responses to its specific threat (*Prestemon, 01.SRS.D.1, Southern Research Station*).

- The wildland-urban interface areas are where firefighting is most challenging; damage to communities, homes, and property is at the greatest risk; and where danger to human life is greatest. However, specific locations, classifications (i.e., city, suburban), and the extent of the wildland-urban interface in terms of distance from the urban boundary into the wildland area, are not well-defined. Scientists are developing valid methods for estimating housing density at a fine scale over a long period (1940-2030) across the United States. Two thousand wildland-urban interface maps for the United States, States, and regions were completed. The identification of wildland-urban interface communities at risk from fire as required under the NFP will be facilitated by these maps. Work was completed on decadal housing density backcast, decadal housing density projection, decadal wildland-urban interface change backcast, wildland-urban interface change predictions, and tabular statistics (wildland-urban interface area and number of housing units, interface versus intermix). Initial projections of wildland-urban interface change over time, and analysis of historical changes in the wildland-urban interface were completed. Through this effort, it will be possible to clearly delineate wildland-urban interface areas and track their growth and change over time (*Dwyer, 02.NCS.D.1, North Central Research Station*).

- A growing body of information exists on the long-term effects of fire on processes that determine sustainability (ecological, economic, and social) and how to restore fire-dominated ecosystems. However, a huge gap exists between what scientists know and what the management community is able to access and apply on the land. A content management system was completed that will allow authors, editors, and reviewers to access encyclopedia material on southern fire science directly through the Internet. The encyclopedia also will help community leaders, land managers, and landowners make more informed decisions by deepening their understanding of the social, economic, and political implications of fire, fuels, and recovery strategies (*Kennard, 02.SRS.D.1, Southern Research Station*).

- Although fire is increasingly recommended as a vegetation management tool on both public and private lands, controversy often inhibits its use. A lack of communication and understanding between land managers and the public contributes to these difficulties. This project is designed to offer a remedy by gathering historical and contemporary information on public knowledge, beliefs, attitudes, and practices related to fire use and fuels management in the Southwest (New Mexico and Arizona) and by providing these data to land managers in a user-friendly format. Researchers are also examining the factors contributing to successful public involvement approaches for fire and fuels management planning. Results will assist land managers in designing and implementing successful, socially acceptable fire and fuels management policies and programs (*Raish, 02.RMS.D.1, Rocky Mountain Research Station*).

- Researchers examined the attitudes, beliefs, and behaviors of local residents and area visitors affected by fire events. Results of two studies indicate that recreation visitors are not overly concerned with fire management, although there is some concern with constraints on their behavior such as not being able to have fires in pits or grills, decreased air quality, and traffic delays owing to fire suppression. Managers may need to provide clear messages to visitors about fire management with explanations of why no fires are allowed, why there is decreased air quality, and why there may be traffic delays (*Chavez, 01.PSW.D.1, Pacific Southwest Station*).

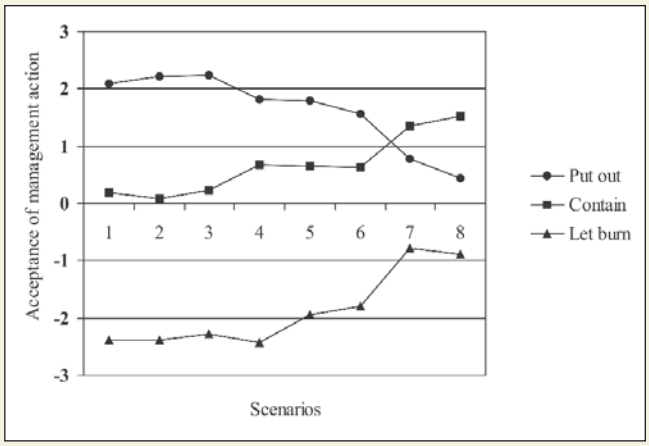
## Community Assistance Highlight

### Recreation and Fire in the Wildland-Urban Interface

**Background:** There is a strong need to understand the human dimensions of wildfire management. Large or small, fires impact property, communities, local institutions, and individuals. More specifically, wildfires may impact a range of locally important quality-of-life or economic outcomes, such as recreation experiences and ecotourism. Also, wildland fire communications and policies should be tailored to local conditions. This suggests that we need a better understanding of human dimensions across geography and subpopulations and how this variation in the social landscape is linked to agency programs and processes. Simply put, we need to link human cognition with wildland fire policies or desired behaviors such as Firewise actions, i.e., acquainting people who live or vacation in fire-prone areas of North America with the challenges of living around interface/intermix wildfire.

**Approach:** A comprehensive model was proposed that includes human values, beliefs, knowledge, attitudes, intentions, and behaviors across different settings and subpopulations. Initial work has focused on the fundamental values and beliefs that individuals hold and relates them to support for fire management issues such as prescribed fire, fuel treatments, fire suppression, and postfire forest health issues. Results suggest that an individual's fundamental values are oriented to specific wildfire management issues by basic beliefs. These value-laden perceptions of wildfire management directly influence individuals' attitudes and norms about wildfire. In turn, these have a direct impact on behaviors related to wildfire management (e.g., creating "defensible space" around a residence or support for agency management actions, such as prescribed burns and mechanical thinning).

**Products:** To date, fire-specific measures of visitors' values and norms toward wildland fire have been developed. Over 3,000 visitors to three geographically dispersed western urban-interface national forests were sampled. Six separate scales were developed for wildland fire beliefs (responsibility, biocentrism, anthropocentrism, freedom, trust, and the benefit and harm of wildfire). Social norms data (acceptability of management practices in different situations) were measured by using combinations of various types of situational factors (i.e., fire origin, recovery time, effects on air quality, and recreation access on private property) across three fire management choices (let burn, contain fire, or put out immediately). Results demonstrate the reliability and validity of the measurement model and provide much needed insight regarding differences in public support for common fire management activities. Another outcome is that the structure of the basic beliefs was relatively consistent across the different strata (national forests). Although this suggests similarity across a diversity of populations, there are differences in support for wildfire actions that can be linked to geography and situational influences. For urban proximate forests, the effect of human origin, quick recovery, and loss of property are notable influences on support for management actions.




*Different combinations of a fire's impacts or origin (scenarios 1-8) can affect the public's acceptance of a particular management action.*

**Application:** Publications and presentations at conferences and individual meetings are transmitting these results to the field and keeping them abreast of the latest developments in the quickly emerging field of human dimensions of wildfire. Specific analyses are being used to better inform policy and public information programs. Managers are aided by knowing that there are some generalized cultural beliefs about wildfire, but also how beliefs differ across settings. The model also provides situation-specific ways to assess public acceptance of fire management choices, such as prescribed fires or fire use (let-burn) decisions.

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**Key Partners:**
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Michigan State University
Colorado State University
California Polytechnic University, San Luis Obispo
University of Florida
U.S. Geological Survey
Bureau of Land Management

## Community Assistance Highlight

### Preventing Residential Fire Disasters in the Wildland-Urban Interface

**Background:** The Forest Service along with the National Fire Protection Association generated the National Wildland-Urban Interface (WUI) Initiative in response to the fire destruction in residential areas during the wildfires of 1985. Since 1990, political attention to homes destroyed and communities evacuated during extreme wildfires has increased. With this increased attention, the WUI Initiative has become the National Wildland-Urban Interface Program (that includes firewise) with a National Wildfire Coordinating Group working team managing the program. Recent policy documents also reflect the importance of destruction of residential areas during wildfires. Documents such as the Cohesive Strategy, the revised Federal Wildland Fire Management Policy, the 10-Year Comprehensive Strategy, the NFP, the Healthy Forests Initiative, and the recently passed Healthy Forests legislation all, in varying degrees, recognize the need for preventing WUI fire disasters.

Although home destruction and the threat of destruction during wildfires have become an important issue, an appropriate, scientifically based definition of the wildland-urban interface fire problem has not been widely incorporated as a basis for management. Proposed management actions are not necessarily based on explicit physical descriptions of how homes ignite related to the characteristics of wildland fires. This suggests that scientists may be missing significant opportunities for effectively and efficiently preventing residential fire disasters during extreme wildfires.

**Approach:** A three-method approach was applied to the problem of homes igniting during wildfires: mathematics was used to model the physics of the problem, experiments verified and augmented the modeling, and investigations of the actual wildland interface fires were used to capture a broader range of conditions. These three methods have converged on how homes ignite during wildfires.

**Products and Tools:** This research indicates that a home's exterior materials and design related to a home's immediate surroundings within 100 feet principally determine the home's ignition potential during extreme wildfire conditions. This area is called the **home ignition zone**. The home ignition zone provides the scientific basis for explicitly defining the problem of residential fire disasters during extreme wildfires. This research indicates that the necessary and sufficient reductions in a home's ignition potential during extreme wildfires can occur within the home ignition zone. Thus, a home's location does not necessarily determine its vulnerability to wildland fire; the condition of the home ignition zone determines its vulnerability. Because the home ignition zone largely falls on private property (perhaps more than one owner), the authority for conducting mitigating actions belongs to the homeowners. Therefore, given that wildland fires are inevitable and that wildfires during extreme conditions are inevitable, the principal actions for preventing residential fire disasters during wildfires must occur on private property. Public land management agencies can facilitate homeowner mitigations, and these agencies may be able to reduce fire intensities and the extent of burning around communities; however, these agencies cannot accomplish the necessary and sufficient actions for preventing residential fire disasters by actions taken beyond the home ignition zone.

*A highly ignitable home zone can result in home destruction without a high-intensity crown fire burning within the home ignition zone. Note that the home is burning without fire in the surrounding vegetation.*

**Application:** This research also provides the basis for the Wildland-Urban Interface Program's mission and vision statements. Specifically, it is nationally applied through the projects sponsored by the National Interagency Wildland-Urban Interface Program. For example, the nationally implemented Firewise Communities U.S.A. Program, inaugurated with the 2002 signing of a memorandum of understanding by the Forest Service, the National Association of State Foresters, and the National Fire Protection Association, uses this home ignition research as its basis for approach. Recognizing that the home ignition zone principally determines home ignition potential, the Firewise Communities U.S.A. process specifically focuses on homeowners and facilitates their principal role in preventing wildland-urban interface fire disasters. As part of the Firewise Communities U.S.A. Program, five national wildland-urban interface coordinators training courses have presented the fundamentals of how homes ignite during wildfires and applications to the assessment of and mitigation of home ignition potential. In addition, this research forms the basis for nationally distributed homeowner and fire service videos. The National Wildland-Urban Interface Program video *Wildfire: Preventing Home Ignitions* shows homeowners and firefighters how homes ignite and how that provides opportunities for mitigating the problem. More than 8,000 videos have been requested and distributed since January 2002. The first video in the National Wildland-Urban Interface Program's *Firefighter Safety in the Wildland-Urban Interface* video series is based on the home ignition research. *The Fire Behavior in the Wildland-Urban Interface* video takes a firefighter through the basics of home ignition and how that provides opportunities for effective fire protection. About 7,500 video sets have been distributed to fire departments nationally.

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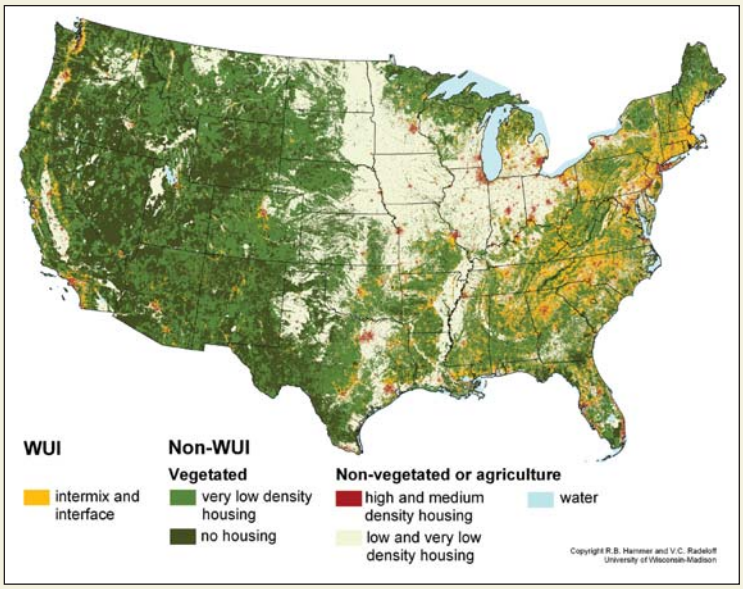
**Key Partner:**
National Interagency Wildland Urban Interface Program/National Wildfire Coordinating Group Working Team

## Community Assistance Highlight

### Mapping the Wildland-Urban Interface and Projecting Its Growth to 2030

**Background:** The wildland-urban interface is a national phenomenon, one that has become widespread across the United States. Defined as "the area where structures and other human developments meet or intermingle with undeveloped wildland," it is where houses and fairly dense vegetation are both present. Issues pertaining to management have increased recently because the wildland-urban interface itself has grown: housing growth occurs in sprawling, wooded suburbs and in rural areas rich in amenities like lakes and forests. Future housing growth promises to further expand the wildland-urban interface.




*The 2000 wildland-urban interface.*

Fire in the wildland-urban interface poses a risk to life, property, and resources, and challenges firefighters because neither municipal nor wildland firefighters are fully equipped to protect a mixture of houses and vegetation. Although the risk of fire is currently the most high-profile, wildland-urban interface issue, there are others. These include forest fragmentation, increasing pressure from recreation activities, wildlife habitat loss and encroachment, human-wildlife conflicts, exotic and invasive pests, and changes in forest productivity when housing growth affects harvesting decisions. The scope and seriousness of the wildland-urban interface issue is still unclear. This research created the first-ever, fine-scale national map of the wildland-urban interface, and will determine its extent, distribution, and change over time.

**Approach:** Researchers created a working definition of the wildland-urban interface, based on the *Federal Register* definition, and combined U.S. Census data and the National Land Cover Dataset (NLCD) to map the wildland-urban interface at high spatial resolution (census blocks, median size 3 acres and 30 meter NLCD land cover pixels) across the lower 48 States. Two wildland-urban interface types were identified, and in both, housing density must be more than one housing unit per 40 acres. Interface wildland-urban interface, where housing is near wildland vegetation, is less than 50 percent vegetated, but within 1.5 miles of an area over 75 percent vegetated. In intermix wildland-urban interface areas, housing and vegetation intermingle; and the area is over 50 percent vegetated. Interface and intermix make up the wildland-urban interface. Some wildland-urban interface areas are at risk of fire, some are not; data are geographic information system-based so that fire risk maps may be overlaid to identify wildland-urban interface areas at risk from fire.

**Products and Application:** The analysis of the extent and distribution of wildland-urban interface in 2000 is complete. Results indicate that 37 percent of all U.S. homes lie within the wildland-urban interface, covering 9 percent of the land area. In 20 of the 48 States mapped, over half the homes are within the wildland-urban interface. Policymakers are already using our results. Congress and the Forest Service Research and Development and State and Private Deputy Areas and the Strategic Planning and Resource Assessment staff in Washington have been briefed. The General Accounting Office has requested maps and data for their recent analysis of the scope of wildland fire management. State foresters and other local-, regional-, and national-level land managers are receiving map images, GIS data, and tabular statistics as they are completed for use in fire hazard mitigation and planning. The utility of the maps for exploring alternative wildland-urban interface definitions and policy scenarios makes it an invaluable tool for strategic wildland fire policymaking at all levels.

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**Key Partner:**
University of Wisconsin, Madison

## Community Assistance Highlight

### The National Database of Wildfire Hazard Mitigation Programs Information

**Background:** The rapid expansion of wildland interface communities has created a complex challenge to wildfire protection managers trying to mitigate wildfire risk to protect lives, property, and natural resources. A major issue is the reduction of hazardous fuels on wildlands adjacent to communities and the creation of defensible space around homes. Public outreach and educational programs, coupled with assistance programs and regulatory policies tailored to the communities' needs, are often used. As officials develop wildfire mitigation strategies, a knowledge base of existing programs and what has been successful in similar communities can greatly enhance planning efforts, while reducing time and cost in implementing new programs.

**Approach:** The program categories include the following approaches to creating fire-safe communities and reducing vegetative fuels:

- Assessments of wildfire risk and designation of high-risk areas assessments are based on the interaction of factors, such as fuel loading, topography, fire history, climate, housing density, and infrastructure for firefighting.
- Public outreach and educational programs include a variety of methods to educate residents about the importance of creating defensible space and to motivate homeowners to take responsibility for their own safety. Educational efforts include demonstration homes, pamphlets, landscaping guides, public displays, radio and television spots, print media, videos, interactive games, classroom programs/teacher education, neighborhood meetings, and workshops for developers.
- Homeowner assistance programs focus on the evaluation of individual homeowners' wildfire risk, provide cost-share assistance for reducing fuels, creating defensible space, chipping of debris, and slash disposal.
- Regulatory programs include State laws and local ordinances and regulations. Regulatory programs most often require developers to design subdivisions in ways that reduce wildfire risk, including reducing fuels before construction, creating fuelbreaks around perimeters, and creating defensible space around homes. Some regulations require existing homes to maintain defensible space standards.

**Products and Tools:** To facilitate the broader dissemination of ideas, the Southern Research Station, in cooperation with Louisiana State University, has developed a central location describing fire protection programs that communities across the country have adopted—http://www.wildfireprograms.usda.gov. The Web site currently describes over 170 programs in 27 States, and new programs are being added continually. Managers are implementing a wide range of approaches to reduce wildfire risk. Therefore, the above categories have been designated on the Web site to assist officials in identifying programs of interest.

*Students from Kittitas County, Washington, schools observe the importance of reducing vegetation and firewise planning around homes as part of the Junior Firewise project.*

**Application:** The Web site files can be searched by State, by program type, or by administrative jurisdiction—State, county, city/town, or fire district. Each file provides a summary of the program components, background for program development, and highlights of the program's most significant activities. Program profiles also include the program manager's contact information and links to pertinent Web sites.

The national wildfire program's database provides a clearinghouse of information where fire protection officials can learn about the strategies communities are using to reduce wildfire risk and how these programs have been funded, administered, and implemented. Web site user requests average 220 per day.

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**Key Partner:**
Louisiana State University

# Appendix

### Table 1—Research Projects[1] and Team Lead Scientists

## Firefighting

| Project ID number | Project title | Team lead scientist(s) | E-mail address |
|---|---|---|---|
| 01.NCS.A.1 | National and regional fire weather dynamics: improved methods for high-resolution forecasting of fire weather and smoke transport | Warren E. Heilman | wheilman@fs.fed.us |
| 01.NCS.A.2 | Assessing vulnerability of populations to wildfire in the North Central Region **(98-1-5-03)** | Robert G. Haight<br>David T. Cleland | rhaight@fs.fed.us<br>dcleland@fs.fed.us |
| 01.NCS.A.3 | FIA pilot test of a fuel condition monitoring system | Dennis May | dmay@fs.fed.us |
| 01.PNW.A.1 | A modeling framework for real-time predictions of cumulative smoke impacts ("BlueSky") **(98-1-9-05, 98-1-9-06, 01-1-6-07, 01-1-6-08)** | Sue A. Ferguson | sferguson@fs.fed.us |
| 01.PNW.A.2 | Estimating haze from prescribed and wildland fires **(98-1-1-05, 98-1-1-06, 98-1-9-05, 01-1-6-01)** | David V. Sandberg | dsandberg@fs.fed.us |
| 01.PNW.A.3 | Seasonal prediction of national fire risks and impacts **(98-1-1-06)** | Ronald P. Neilson | rneilson@fs.fed.us |
| 01.PNW.A.4 | Fuel moisture mapping and combustion limits **(98-1-9-06)** | David V. Sandberg | dsandberg@fs.fed.us |
| 01.PSW.A.1 | Risks to fish and wildlife from wildfire and landscape treatments | Danny C. Lee | dclee@fs.fed.us |
| 01.PSW.A.2 | An initial attack model for fire management planning **(01-1-7-06)** | Marc Wiitala | mrwiitala@fs.fed.us |
| 01.PSW.A.3 | Fire behavior in live fuels | David R. Weise | dweise@fs.fed.us |
| 01.PSW.A.4 | Real-time remote sensing of fire properties | Philip J. Riggan | priggan@fs.fed.us |
| 01.PSW.A.5 | Weather models for area coordination centers | Francis Fujioka | ffujioka@fs.fed.us |
| 01.RMS.A.1 | Improving decisions for fuel treatment options **(98-1-8-06, 01-1-3-22)** | Greg J. Jones<br>Jimmie Chew | jgjones@fs.fed.us<br>jchew@fs.fed.us |
| 01.RMS.A.2 | Real-time fire monitoring nationwide **(01-1-5-03)** | Wei Min Hao | whao@fs.fed.us |
| 01.RMS.A.3 | New technology for monitoring smoke characteristics | Wei Min Hao | whao@fs.fed.us |
| 01.RMS.A.4 | Remote sensing, GIS, and landscape assessment tools for fire management **(98-1-1-07, 99-1-3-29, 00-1-3-19, 01-1-1-6)** | Robert E. Keane | rkeane@fs.fed.us |
| 01.RMS.A.5 | Fire management strategies for wilderness and other protected areas **(99-1-3-16, 01-1-1-05, 01-1-3-12)** | Carol Miller<br>Anne E. Black | cmiller04@fs.fed.us<br>aeblack@fs.fed.us |
| 01.SRS.A.1 | Prediction of fire weather and smoke impacts in the Southeast | Gary L. Achtemeier | gachtemeier@fs.fed.us |
| 01.SRS.A.2 | Tradeoffs of alternative vegetation management strategies **(01-1-2-09)** | Jeffrey P. Prestemon | jprestemon@fs.fed.us |
| 01.SRS.A.3 | Establishing a wildland-urban interface research and technology transfer unit for the South | Pete Roussopoulos | proussopoulos@fs.fed.us |
| 01.SRS.A.4 | Long-range forecasting of fire season severity | Scott Goodrick | sgoodrick@fs.fed.us |
| 01.SRS.A.5 | Southern regional models for predicting smoke movement | Gary L. Achtemeier | gachtemeier@fs.fed.us |
| 02.NES.A.1 | Regional climate and fire danger modeling for the New Jersey Pine Barrens | John Hom | jhom@fs.fed.us |
| 02.PSW.A.1 | Improving monitoring and modeling of smoke contributions to regional haze **(01-1-05-06)** | Andrzej Bytnerowicz | abytnerowicz@fs.fed.us |
| 02.RMS.A.1 | Enhanced prediction of fire weather and smoke impacts in the Rocky Mountains and Southwest | Karl Zeller | kzeller@fs.fed.us |
| 02.RMS.A.2 | A nationwide system to generate a daily emissions inventory of pollutants from fires (01-1-5-03) | Wei Min Hao | whao@fs.fed.us |

[1] Number in bold and parentheses following some titles indicates links to Joint Fire Science projects listed in table 3.

**Table 1—Research Projects[1] and Team Lead Scientists (continued)**

## Rehabilitation and restoration

| Project ID number | Project title | Team lead scientist(s) | E-mail address |
|---|---|---|---|
| 01.PNW.B.1 | Predicting spread of invasive species after fuel reduction treatments and postfire disturbance **(99-S-1, 01B-3-3-16)** | Edward J. DePuit | ejdepuit@fs.fed.us |
| 01.PSW.B.1 | Effectiveness of postfire emergency rehabilitation treatments in the West **(98-1-4-12, 01-3-2-08)** | Jan Beyers<br>Peter R. Robichaud | jbeyers@fs.fed.us<br>probichaud@fs.fed.us |
| 01.RMS.B.1 | Hydrologic and geomorphic consequences of wildfire and fuels management options in southwestern forest and woodland ecosystems **(99-S-1, 99-1-3-13)** | Daniel G. Neary | dneary@fs.fed.us |
| 01.RMS.B.2 | Native plant materials for restoration of sagebrush steppe and pinyon-juniper communities **(00-1-1-03)** | E. Durant McArthur | dmcarthur@fs.fed.us |
| 01.RMS.B.3 | Dynamics of weed invasions and fire in the northern Rockies | George Markin | gmarkin@fs.fed.us |
| 01.RMS.B.4 | Effects of wildfire and fire management options on invasive and exotic species and pathogens **(99-S-1)** | Karen Clancy | kclancy@fs.fed.us |
| 01.RMS.B.5 | Factors affecting Great Basin watersheds' susceptibility to invasive plants **(00-1-1-03, 00-2-15, 01B-3-3-01)** | Jeanne C. Chambers | jchambers@fs.fed.us |
| 01.RMS.B.6 | Patterns of white pine regeneration after fire | Anna Schoettle | aschoettle@fs.fed.us |
| 01.RMS.B.7 | The role of grassland fire in managing exotic and woody plants | Deborah Finch | dfinch@fs.fed.us |
| 02.PNW.B.1 | Response of native and invasive exotic plants to fire and fuel reduction treatments in the interior Pacific Northwest | Catherine Parks | cparks01@fs.fed.us |
| 02.RMS.B.1 | Characterizing risks of wildfire and fuels management in aquatic ecosystems | Bruce Rieman<br>Jason B. Dunham | brieman@fs.fed.us<br>jbdunham@fs.fed.us |
| 02.SRS.B.1 | Modeling the effects of wildfire on sediment and nutrient loads in the Southeastern United States | James M. Vose | jvose@fs.fed.us |

## Hazardous-fuels reduction

| | | | |
|---|---|---|---|
| 01.FPL.C.1 | Hazardous-fuels reduction through harvesting underutilized trees and forest undergrowth and producing three-dimensional structural products | John F. Hunt | jfhunt@fs.fed.us |
| 01.FPL.C.2 | Utilization of small-diameter crooked timber for use in laminated structural boards through development of new sawing, laminating, and drying processes | John F. Hunt | jfhunt@fs.fed.us |
| 01.NCS.C.1 | Optimizing fuel reductions in time and space **(01-1-3-43)** | David Lytle | dlytle@fs.fed.us |
| 01.NCS.C.2 | Managing risk of fire on human and ecological communities in the wildland-urban interface | Eric Gustafson<br>Tom Crow | egustafson@<br>tcrow@fs.fed.us |
| 01.NES.C.1 | Fuels and fire behavior in the central hardwoods **(99-S-1)** | Matthew B. Dickinson | mbdickinson@fs.fed.us |
| 01.PNW.C.1 | Ground-based support for mapping fuel and fire hazard **(98-1-1-05, 98-1-1-06, 01-1-7-02)** | David V. Sandberg | dsandberg@fs.fed.us |
| 01.PNW.C.2 | Fuel reduction and forest restoration strategies that sustain key habitats and species in the interior Northwest **(99-S-1, 01-1-3-25, 01-1-6-01)** | John F. Lehmkuhl | jlehmkuhl@fs.fed.us |
| 01.PSW.C.1 | Effects of fuel reductions on stream ecosystems **(00-2-05)** | Carolyn T. Hunsaker | chunsaker@fs.fed.us |
| 01.PSW.C.2 | Alternatives to fire for fuel reduction in California shrublands within coniferous forest | Robert F. Powers | rpowers@c-zone.net |
| 01.PSW.C.3 | The effect of prescribed fire on hydrologic and soil processes that affect erosion in semiarid systems | Ken Hubbert<br>Mary O'Dea | khubbert@fs.fed.us<br>modea@fs.fed.us |

**Table 1—Research Projects[1] and Team Lead Scientists (continued)**

| Project ID number | Project title | Team lead scientist(s) | E-mail address |
|---|---|---|---|
| 01.PSW.C.4 | Effects of wildfire and fuel treatments on California spotted owl | John J. Keane<br>Peter A. Stine | jkeane@fs.fed.us<br>pstine@fs.fed.us |
| 01.RMS.C.1 | Impacts of exotic weeds on fuel loading and fire regimes **(00-1-1-03)** | Nancy L. Shaw | nshaw@fs.fed.us |
| 01.RMS.C.2 | The relationship between forest structure and fire severity **(99-1-1-04, 00-2-19, 00-2-20)** | Dennis E. Ferguson<br>Theresa B. Jain | deferguson@fs.fed.us<br>tjain@fs.fed.us |
| 01.RMS.C.3 | Impact of fuel management treatments on forest soil erosion and production **(98-1-4-12)** | William J. Elliot<br>Deborah Page-Dumroese | welliot@fs.fed.us<br>ddumroese@fs.fed.us |
| 01.RMS.C.4 | Management alternatives for fire-dependent ecosystems in Colorado and the Black Hills **(98-1-5-01)** | Linda A. Joyce | ljoyce@fs.fed.us |
| 01.RMS.C.5 | Improved guidelines for fuels management in southwestern ponderosa pine and pinyon-juniper forests in wildland-urban interface areas **(99-S-1, 00-U-01)** | Carl Edminster | cedminster@fs.fed.us |
| 01.RMS.C.6 | Restoration techniques in lodgepole pine forests | Ward McCaughey | wmccaughey@fs.fed.us |
| 01.RMS.C.7 | Use of remote sensing to examine disturbance effects | John E. Lundquist | jlundquist@fs.fed.us |
| 01.RMS.C.8 | Riparian ecosystem dynamics in relation to fire in the Rocky Mountains **(01-1-3-19)** | Deborah Finch | dfinch@fs.fed.us |
| 01.SRS.C.1 | Wildfire risk in the Eastern United States | Steve McNulty | steve_mcnulty@ncsu.edu |
| 01.SRS.C.2 | Quantifying the ecological and economic tradeoffs of fire and fire surrogate options—Piedmont and Southern Appalachian Mountains **(99-S-1, 01-1-4-02)** | Thomas A. Waldrop | twaldrop@fs.fed.us |
| 01.SRS.C.3 | Quantifying the tradeoffs of fire and fuels management options—longleaf and slash pine ecosystems of the Atlantic and Gulf Coastal Plain **(99-S-1)** | Kenneth W. Outcalt | koutcalt@fs.fed.us |
| 01.SRS.C.4 | A system for mechanized fuel reduction at the wildland-urban interface | John Stanturf | jstanturf@fs.fed.us |
| 01.SRS.C.5 | Fire and herbicide combinations to reduce fire intensity **(00-2-27, 01-1-3-11)** | Joseph J. O'Brien | jjobrien@fs.fed.us |
| 02.FPL.C.1 | Developing tools to assess economic feasibility of processing wood removed in the course of hazardous-fuels reduction | Ken Skog | kskog@fs.fed.us |
| 02.PNW.C.1 | Integrated approach for assessing fire risk, disturbance patterns, and conducting analysis of fuel treatment strategies on large landscapes | Jamie Barbour | jbarbour01@fs.fed.us |
| 02.PSW.C.1 | Fire and fuels management, landscape dynamics, and fish and wildlife resources: study design for integrated research on the Plumas and Lassen National Forests | Peter Stine | pstine@fs.fed.us |
| 02.RMS.C.1 | Environmental and economic impacts of biomass reduction **(98-1-4-12, 01-3-2-08)** | William J. Elliot | welliot@fs.fed.us |
| 02.RMS.C.2 | Effects of wildland fire and fuel treatments on terrestrial vertebrates in intermountain forests **(01-1-3-25)** | William Block<br>Victoria Saab | wblock@fs.fed.us<br>vsaab@fs.fed.us |

**Table 1—Research Projects[1] and Team Lead Scientists (continued)**

## Community assistance

| Project ID number | Project title | Team lead scientist(s) | E-mail address |
|---|---|---|---|
| 01.NCS.D.1 | Modeling people's responses to landscape treatments **(99-1-2-08, 99-1-2-10)** | John F. Dwyer | jdwyer@fs.fed.us |
| 01.NCS.D.2 | Community partnerships | Pamela J. Jakes | pjakes@fs.fed.us |
| 01.PSW.D.1 | Recreation and fire in the wildland-urban interface **(99-1-2-10)** | Deborah Chavez<br>James Absher | dchavez@fs.fed.us<br>jabsher@fs.fed.us |
| 01.PSW.D.2 | Firewise residential landscapes | Greg McPherson | egmcpherson@ ucdavis.edu |
| 01.RMS.D.1 | Building consensus on fire management | Brian Kent | bkent@fs.fed.us |
| 01.RMS.D.2 | Preventing residential fire disasters at the wildland-urban interface | Jack D. Cohen | jcohen@fs.fed.us |
| 01.SRS.D.1 | Impact of wildfires on local economies **(01-1-2-09)** | Jeffrey P. Prestemon | jprestemon@fs.fed.us |
| 01.SRS.D.2 | Fire protection in residential expansion areas | Terry Haines | thaines01@fs.fed.us |
| 02.NCS.D.1 | Mapping the wildland-urban interface and projecting its growth to 2030 **(99-1-2-08, 99-1-2-10)** | John F. Dwyer | jdwyer@fs.fed.us |
| 02.RMS.D.1 | Community knowledge, beliefs, attitudes, and practices concerning fire and fuels management in southwestern ecosystems | Carol Raish | craish@fs.fed.us |
| 02.SRS.D.1 | An Internet-based encyclopedia of southern fire science and management knowledge | Deborah Kennard | dkennard@fs.fed.us |

*Magge Brassil and Jeb Doran record vegetation recovery following wildfire on the Bitterroot National Forest.*

**Table 2—Summary of Accomplishments in Fiscal Year 2003**

| Accomplishment | Firefighting | Rehabilitation and restoration | Hazardous-fuels reduction | Community assistance | Total |
|---|---|---|---|---|---|
| Studies initiated | 75 | 33 | 86 | 39 | 233 |
| Agreements/contracts established | 53 | 28 | 56 | 31 | 168 |
| $$ value of agreements (1,000s) | 2,658 | 805 | 2,812 | 1,901 | 8,176 |
| Permanent scientists/professionals hired | 6.61 | 0 | 3.5 | 1 | 11 |
| Term scientists/professionals hired | 9.50 | 4 | 16 | 1 | 31 |
| Permanent technicians hired | 0 | 0 | 4 | 0 | 4 |
| Term/temp. technicians hired | 10.25 | 48 | 90 | 6 | 154.1 |
| Refereed publications | 39 | 34 | 30 | 8 | 111 |
| Nonrefereed publications | 47 | 34 | 49 | 10 | 140 |
| Presentations at scientific conferences | 151 | 131 | 139 | 41 | 462 |
| User bulletins, leaflets produced | 34 | 7 | 17 | 9 | 67 |
| Decision-support tools, models developed | 42 | 5 | 14 | 3 | 64 |
| Demonstrations, tours hosted | 60 | 24 | 57 | 12 | 153 |
| Significant consultations with: | | | | | |
| Regions, national forests, districts | 64 | 68 | 83 | 44 | 259 |
| States, State foresters | 38 | 18 | 29 | 27 | 112 |
| Tribal governments | 2 | 3 | 4 | 2 | 11 |
| County, local, governments, | 5 | 14 | 7 | 54 | 80 |
| Other | 35 | 4 | 42 | 75 | 156 |
| Short courses, workshops, training offered | 31 | 18 | 46 | 11 | 106 |
| Total number of attendees | 603 | 912 | 1,412 | 968 | 3,895 |
| Communities assisted | 1 | 4 | 29 | 23 | 57 |
| Fire management units assisted | 30 | 6 | 36 | 15 | 87 |

**Table 3—Joint Fire Science Program Research Projects[1] With Links to Forest Service National Fire Plan Research Projects**

| Project ID number | Project title | Team lead scientist |
|---|---|---|
| 98-1-1-05 | Photo series for major natural fuel types of the United States–phase II **(01.PNW.A.1, 01.PNW.C.1)** | Roger Ottmar |
| 98-1-1-06 | Application of a fuel characterization system for major fuel types of the contiguous United States and Alaska **(01.PNW.A.2, 01.PNW.A.3, 01.PNW.C.1)** | Roger Ottmar |
| 98-1-1-07 | Mapping fuels using remote sensing and biophysical modeling **(01.RMS.A.4)** | Robert Keane |
| 98-1-4-12 | Risk assessment of fuel management practices on hillslope erosion processes **(01.PSW.B.1, 01.RMS.C.3, 02.RMS.C.1)** | Peter Robichaud |
| 98-1-5-01 | Fire regimes and fuel treatments: a synthesis with manager feedback **(01.RMS.C.4)** | Phil Omi |
| 98-1-5-03 | Characterizing historical and contemporary fire regimes in the Lake States **(01.NCS.A.2)** | David Cleland |
| 98-1-8-06 | A risk-based comparison of potential fuel treatment tradeoff models **(01.RMS.A.1)** | David Weise |
| 98-1-9-05 | Implementation of an improved emission production model **(01.PNW.A.1, 01.PNW.A.2)** | David Sandberg |
| 98-1-9-06 | Modification and validation of fuel consumption models for shrub and forested lands in the Southwest, Pacific Northwest, Rockies, Midwest, Southeast, and Alaska **(01.PNW.A.1, 01.PNW.A.4)** | Roger Ottmar |
| 99-S-1 | A national study of the consequences of fire and fire surrogate treatments **(01.PNW.B.1, 01.RMS.B.1, 01.RMS.B.4, 01.NES.C.1, 01.PNW.C.2, 01.RMS.C.5, 01.SRS.C.2, 01.SRS.C.3)** | Jim McIver |
| 99-1-1-04 | Development and delivery of the fire and fuels extension to the Forest Vegetation Simulator for use by stakeholders to the Joint Fire Science Program **(01.RMS.C.2)** | Nicholas Crookston |
| 99-1-2-08 | Evaluating public response to wildland fuels management: factors that influence acceptance of practices and decision processes **(01.NCS.D.1, 02.NCS.D.1)** | Bruce Shindler |
| 99-1-2-10 | Demographic and geographic approaches to predicting public acceptance of fuel management at the wildland-urban interface **(01.NCS.D.1, 01.PSW.D.1, 02.NCS.D.1)** | Jeremy Fried |
| 99-1-3-13 | Carbon and nitrogen cycling by microbial decomposers following thinning and burning in a southwestern ponderosa pine ecosystem **(01.RMS.B.1)** | Daniel Neary |
| 99-1-3-29 | Southern Utah fuels management demonstration project **(01.RMS.A.4)** | Kevin Ryan |
| 00-1-1-03 | Changing fire regimes, increased fuel loads, and invasive species: effects on sagebrush steppe and pinyon-juniper ecosystems **(01.RMS.B.2, 01.RMS.B.5, 01.RMS.C.1**) | Jeanne Chambers |
| 00-1-3-19 | Monitoring fire effects at multiple scales: integrating standardized field data collection with remote sensing to assess fire effects **(01.RMS.A.4)** | Robert Keane |
| 00-U-01 | Cerro Grande postfire inventory and analysis **(01.RMS.C.5)** | Carl Edminster |
| 00-2-05 | Kings River and Lake Tahoe Basin demonstration sites for fuel treatments **(01.PSW.C.1)** | Carolyn Hunsaker |
| 00-2-15 | A demonstration area on ecosystem response to watershed-scale burns in Great Basin pinyon-juniper woodlands **(01.RMS.B.5)** | Jeanne Chambers |
| 00-2-19 | Stand and fuel treatments for restoring old-growth ponderosa pine forests in the interior West (Boise Basin Experimental Forest) **(01.RMS.C.2)** | Russell Graham |
| 00-2-20 | Treatments that enhance the decomposition of forest fuels for use in partially harvested stands in the moist forests of the northern Rocky Mountains (Priest River Experimental Forest) **(01.RMS.C.2)** | Russell Graham |
| 00-2-27 | Maintaining longleaf pine woodlands: is mechanical shearing a surrogate for prescribed burning? **(01.SRS.C.5)** | Jeff Glitzenstein |
| 01-1-1-05 | Can wildland fire use restore historical fire regimes in wilderness and other unroaded lands? **(01.RMS.A.5)** | Carol Miller |
| 01-1-1-6 | Historical wildland fire use: lessons to be learned from 25 years of wilderness fire management **(01.RMS.A.4)** | Matthew Rollins |
| 01-1-2-09 | A national study of the economic impacts of biomass removals to mitigate wildfire damages on Federal, State, and private lands **(01.SRS.A.2, 01.SRS.D.1)** | Jeffrey Prestemon<br>Karen Lee Abt |

**Table 3—Joint Fire Science Program Research Projects[1] With Links to Forest Service National Fire Plan Research Projects (continued)**

| Project ID number | Project title | Team lead scientist |
|---|---|---|
| 01-1-3-11 | Duff consumption and southern pine mortality **(01.SRS.C.5)** | Kevin Hiers |
| 01-1-3-12 | Effects of prescribed and wildland fire on aquatic ecosystems in western forests **(01.RMS.A.5)** | David Pilliod |
| 01-1-3-19 | Effects of fuels-reduction and exotic plant removal on vertebrates, vegetation, and water resources in southwestern riparian ecosystems **(01.RMS.C.8)** | Deborah Finch |
| 01-1-3-22 | Optimizing landscape treatments for reducing wildfire risk and improving ecological sustainability of ponderosa pine forests within mixed-severity fire regimes **(01.RMS.A.1)** | Merrill Kaufman |
| 01-1-3-25 | Prescribed fire strategies to restore wildlife habitat in ponderosa pine forests of the intermountain West **(01.PNW.C.2, 02.RMS.C.2)** | Victoria Saab |
| 01-1-3-43 | Fire, management, and land mosaic interactions: a generic spatial model and toolkit from stand to landscape scales **(01.NCS.C.1)** | Thomas Crow |
| 01-1-4-02 | Fuel classification for the southern Appalachian Mountains using Hyperspectral Image Analysis and Landscape Ecosystem Classification **(01.SRS.C.2)** | Tom Waldrop |
| 01-1-5-03 | Automated forecasting of smoke dispersion and air quality using NASA Terra and Aqua satellite data **(01.RMS.A.2, 02.RMS.A.2)** | Wei Min Hao |
| 01-1-5-06 | Improving model estimates of smoke contributions to regional haze using low-cost sampler systems **(02.PSW.A.1)** | Andrezj Bytnerowicz |
| 01-1-6-01 | Fire and climatic variability in the inland Pacific Northwest: integrating science and management **(01.PNW.A.2, 01.PNW.C.2)** | David Peterson |
| 01-1-6-07 | Assessing the value of mesoscale models in predicting fire danger **(01.PNW.A.1)** | Sue Ferguson |
| 01-1-6-08 | Predicting lightning risk **(01.PNW.A.1)** | Sue Ferguson |
| 01-1-7-02 | Photo series for major natural fuel types of the United States—phase III **(01.PNW.C.1)** | Roger Ottmar |
| 01-1-7-06 | Techniques for creating a national interagency process for predicting preparedness levels **(01.PSW.A.2)** | Gerry Day |
| 01-3-2-08 | Risk assessment of fuel management practices on hillslope erosion processes (Phase II) **(01.PSW.B.1, 02.RMS.C.1)** | Peter Robichaud |
| 01B-3-3-01 | Effects of fire and rehabilitation seeding on sage grouse habitat in the pinyon-juniper zone **(01.RMS.B.5)** | Jeanne Chambers |
| 01B-3-3-16 | Effects of season and interval of prescribed burns in a ponderosa pine ecosystem **(01.PNW.B.1)** | Walter Thies |

[1] Number in bold and parentheses following some titles indicates links to Forest Service National Fire Plan projects listed in table 1.

*Installing thermographs to measure water temperature in Upper Cherry Creek, in the morning before the main burn period. Documenting riparian fire behavior on film. Left to right: Damian Cremins, biological technician; Matthew Burbank, biological technician; Ethan Mace, research crew boss.*

**Table 4—2003 Research Partners and Cooperators for Forest Service National Fire Plan Research**

| Partner/Cooperator | Firefighting | Rehabilitation and restoration | Hazardous-fuels reduction | Community assistance |
|---|---|---|---|---|
| **Educational institution** | | | | |
| Auburn University (AL) | | | √ | √ |
| Australian National University | √ | | | |
| Brigham Young University (UT) | √ | √ | | |
| California Polytechnic University, San Luis Obispo | | | | √ |
| California State University, Fresno | | | √ | |
| Capilano College, N. Vancouver, BC | √ | | | |
| Clemson University (SC) | | | √ | √ |
| Colorado State University | √ | √ | √ | √ |
| Columbia University | | | √ | |
| Desert Research Institute | √ | | | |
| Eastern Oregon University | | √ | | |
| Louisiana State University | | | | √ |
| Michigan State University | √ | | | |
| Montana State University | √ | √ | √ | |
| New Mexico State University | | | | |
| North Carolina State University | √ | | √ | √ |
| Northern Arizona University | | √ | √ | |
| Ohio State University | | | √ | |
| Ohio University | | | √ | |
| Oregon State University | | √ | √ | √ |
| Penn State University | | | | √ |
| Rutgers University Pinelands Research Station (NJ) | √ | | | |
| San Diego State University | | | | √ |
| Scripps Institution of Oceanography (CA) | √ | | | |
| South Dakota School of Mines | √ | | | |
| Southern Oregon University | | | | √ |
| State University of New York, Albany | √ | | | |
| Technological University of Plant Polymers (Russia) | | | √ | |
| University of Arizona | | √ | √ | |
| University of California, Berkeley | √ | | √ | |
| University of California, Davis | | | √ | |
| University of California, Riverside | | | √ | |
| University of California, Santa Barbara | √ | | √ | |
| University of Florida | | | √ | |
| University of Georgia | √ | | √ | √ |
| University of Hawaii | √ | | | |
| University of Idaho | √ | √ | | |
| University of Illinois | | | √ | |
| University of Massachusetts | | | | √ |
| University of Missouri, Columbia | | | √ | |
| University of Minnesota | | | √ | |
| University of Montana | | | √ | |

**Table 4—2003 Research Partners and Cooperators for Forest Service National Fire Plan Research (continued)**

| Partner/Cooperator | Firefighting | Rehabilitation and restoration | Hazardous-fuels reduction | Community assistance |
|---|---|---|---|---|
| **Educational institution (continued)** | | | | |
| University of Nevada | √ | √ | | |
| University of New Mexico | | | √ | |
| University of North Carolina | | | √ | |
| University of Oklahoma | | | √ | |
| University of Washington | √ | √ | √ | |
| University of Wisconsin, Madison | √ | | √ | √ |
| University of Wyoming | | | √ | |
| Virginia Polytechnic Institute and State University | | | | √ |
| Washington State University | √ | | | |
| Yale University | | | √ | |
| **Private companies** | | | | |
| Adaptive Management Services, Pacific Southwest Region (CA) | | | √ | |
| Air Science Corp. (OR) | | | √ | |
| Associated Arborists of Chico (CA) | | | √ | |
| Bearstar Enterprise (MT) | √ | | | |
| Boise Cooperation | | | √ | |
| Bolton-Emerson Americas, Inc. (MA) | | | √ | |
| Carroll Nelson Associates (MT) | √ | | | |
| Crescent Technology (WI) | | | √ | |
| David Cook Tillage (CA) | | | √ | |
| Digital Visions Enterprise Group (OR) | √ | | | |
| ESSA Technologies (Canada) | | | √ | |
| FireVision (WA) | √ | | | |
| GC Micro Corp. (CA) | √ | | | |
| Genesis Laboratory | | | √ | |
| Geo Data (MT) | √ | | | |
| Hollis Marriott (WY) | √ | | | |
| INTECS International, Inc. (CO) | | | | √ |
| Integrated Resource Solutions (CA) | | | | √ |
| Jack Losensky | | | √ | |
| Kruger Enterprises (MA) | | | √ | |
| Longview Fiber Company | | | √ | |
| Mantech Environmental Technology, Inc. (NC) | | | √ | |
| MATCOM (CO) | | | √ | |
| METI (TX) | | | √ | |
| Patrick Freedom (MT) | √ | | | |
| PBS Environmental Consultants (WA) | | | √ | |
| Plumb Creek Timber Company | | | √ | |
| R. Lamar (CA) | √ | | | |
| Space Instruments, Inc. (CA) | √ | | | |
| Systems for Environmental Management (MT) | | | | √ |

**Table 4—2003 Research Partners and Cooperators for Forest Service National Fire Plan Research (continued)**

| Partner/Cooperator | Firefighting | Rehabilitation and restoration | Hazardous-fuels reduction | Community assistance |
|---|---|---|---|---|
| **Private companies (continued)** | | | | |
| Swan Ecosystem Center | | | √ | |
| Technology Service Corp. (CO) | √ | | | |
| Titan Systems, Inc. (OR) | | | √ | |
| TSI, Inc. (MN) | √ | | | |
| Wyoming Sawmill | | | √ | |
| **Government** | | | | |
| Beaverhead-Deerlodge National Forest | √ | | | |
| Bitterroot National Forest | √ | | | |
| Forest Service Forest Inventory and Analysis, Washington, DC | | √ | | |
| Interagency Geographic Area Coordination Centers | √ | | | |
| Los Alamos National Laboratory (NM) | √ | | | |
| National Aeronautics and Space Administration | √ | | √ | |
| National Forest System | √ | | √ | |
| National Oceanic and Atmospheric Administration (TN) | √ | | | |
| National Park Service | | | √ | |
| Pacific States Marine Fisheries Commission (OR) | √ | | | |
| Peaks Ranger District, Coconino National Forest (AZ) | | | √ | |
| U.S. Department of the Interior | √ | | | |
| U.S. Environmental Protection Agency | √ | | | |
| U.S. Fish and Wildlife Service | | | √ | |
| U.S. Geological Survey | | | √ | |
| **State government** | | | | |
| Minnesota Department of Natural Resources | √ | | | |
| New Jersey Forest Fire Service | √ | | | |
| New Mexico Department of Agriculture | | | √ | |
| North Carolina Wildlife Resources Commission | | | √ | |
| Northern Region Western Montana Planning Zone | √ | | | |
| State Forest Fire Compact | √ | | | |
| Washington Department of Natural Resources | | | √ | |
| **Nongovernment organizations** | | | | |
| Duck Creek Association (OR) | | | √ | |
| Watershed Research and Training Center (CA) | √ | | | |
| Middle Rio Grande Conservancy District (NM) | | | √ | |
| National Center for Atmospheric Research | | | √ | |
| National Council for Air and Stream Improvement, Inc. | | | √ | |
| Nature Conservancy | | | √ | |
| Point Reyes Bird Conservatory (CA) | | | √ | |
| Tall Timbers Research Station (FL) | | | | √ |
| **Tribe** | | | | |
| Southern Ute Tribe | | | √ | |

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