Research Highlights

Fire, Fuel, and Smoke Science Program
Missoula Fire Sciences Laboratory

2017

Edited and compiled by Colin Hardy, Thomas Dzomba, and Audrey Peterson
FIRE, FUEL, AND SMOKE
SCIENCE PROGRAM
Missoula Fire Sciences
Laboratory
Rocky Mountain Research
Station
U.S. Forest Service
5775 U.S. Highway 10 West
Missoula, MT 59808-9361
www.firelab.org
Contents
Fire, Fuel, and Smoke Science Program................................................................. 5
Fire Modeling Institute (FMI) ..................................................................................... 9
   Fire Effects Information System (FEIS) ................................................................. 10
Partnerships.................................................................................................................. 11
Physical Fire Processes............................................................................................... 13
   Improving firefighter safety.................................................................................... 13
   Convective ignition ................................................................................................. 14
   Burning rate ............................................................................................................. 15
3D Fuel and Fire Modeling......................................................................................... 16
Reconstructing U.S. Wildland Fire Trends................................................................. 17
Fuel Dynamics............................................................................................................. 18
   Live Fuels and Fire Behavior Research ................................................................. 18
   Fuel PARticle DYnamics (FPARDY) .................................................................... 19
   Photoload ................................................................................................................ 20
   Ponderosa Pine Restoration at Lick Creek .............................................................. 21
   Lubrecht Fire-Fire Surrogate Study ....................................................................... 23
Smoke Emissions and Dispersion ............................................................................. 25
   Missoula Fire Lab Wildfire Emission Inventory ...................................................... 25
   Impacts of wildfire emissions on Salt Lake City ..................................................... 27
   Fires in Northern Eurasia ........................................................................................ 28
   Near Real-Time Burned Area Mapping with VIIRS .............................................. 29
Fire Ecology.................................................................................................................. 31
   Lodgepole fire history............................................................................................. 31
   Prairie-Forest Edge Fire History ............................................................................ 32
   Fire-Induced Tree Mortality .................................................................................... 33
   California tree mortality .......................................................................................... 34
   Wildfire effects in grand fir-hemlock forests ......................................................... 34
   Fire: A Vaccine for the Forest? .............................................................................. 35
   FIRESEV East ............................................................................................................ 36
   Whitebark Pine Climate Change (WBPC C) ........................................................... 38
   Archiving tree-ring specimens and data for the future ......................................... 39
Fire and Fuel Management Strategies....................................................................... 40
   Structures Lost to Wildfire 1999-2016 ................................................................. 40
   Wind and Slope effects on Flame Scaling in Laboratory Fires ............................... 41
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old tree responses</td>
<td>42</td>
</tr>
<tr>
<td>Landscape risk – drivers, tradeoffs, and feedbacks</td>
<td>42</td>
</tr>
<tr>
<td>Bark beetle outbreaks in lodgepole pine</td>
<td>44</td>
</tr>
<tr>
<td>Science Synthesis and Delivery</td>
<td>45</td>
</tr>
<tr>
<td>Conservation Education</td>
<td>45</td>
</tr>
<tr>
<td>FireWorks Educational Program Expands</td>
<td>46</td>
</tr>
<tr>
<td>Wildfire Hazard Assessment - Chelan County, WA</td>
<td>47</td>
</tr>
<tr>
<td>Applications and Products</td>
<td>48</td>
</tr>
<tr>
<td>BehavePlus Fire Modeling System</td>
<td>48</td>
</tr>
<tr>
<td>BehavePlus Online Training Course</td>
<td>48</td>
</tr>
<tr>
<td>Fire Behavior Pocket Guide</td>
<td>49</td>
</tr>
<tr>
<td>FFI – Ecological Monitoring Application</td>
<td>50</td>
</tr>
<tr>
<td>FireFamilyPlus (FFP)</td>
<td>51</td>
</tr>
<tr>
<td>First Order Fire Effects Model (FOFEM)</td>
<td>51</td>
</tr>
<tr>
<td>FuelCalc</td>
<td>52</td>
</tr>
<tr>
<td>Severe Fire Weather Potential Mapping</td>
<td>52</td>
</tr>
<tr>
<td>WIMS Development and Support</td>
<td>53</td>
</tr>
<tr>
<td>WindNinja: Predicting winds for fire management</td>
<td>53</td>
</tr>
<tr>
<td>The Research Continues: The White Cap Story</td>
<td>55</td>
</tr>
<tr>
<td>Publications</td>
<td>57</td>
</tr>
</tbody>
</table>
Our Fire, Fuel, and Smoke Science Program (FFS) was established in 2007 as an outcome of a station-wide restructuring of over 25 independent research units within the Rocky Mountain Research Station (RMRS) into seven consolidated Science Programs (please explore our RMRS website for information on all of the Station’s Science Programs: http://www.fs.fed.us/rmrs/). Nearly 70 scientists, professionals, and technical and administrative support staff in the FFS Program contribute to all six types of research accomplishments: 1. Knowledge Discovery, 2. Knowledge Development, 3. Knowledge Synthesis and Assessment, 4. Modeling and Systems Integration, 5. Special Assignments, and 6. Leadership.

Although the unique assemblage of experimental combustion chamber, wind tunnels, chemistry and fuel processing labs, and place-based Experimental Forests and Ranges (EF&Rs) comprise the core infrastructure by which we accomplish much of this work, I must note that the “lead-off” story about this Program and this place should be about our people. When I speak to community groups and students (especially!), I boast of the diversity of expertise and experience represented by our Program’s workforce. The typical image of fire scientists is of physicists and engineers in white lab coats or, for others, firefighters in yellow shirts wielding clipboards. I often pivot from that image to the message that there is a demonstrated niche in our Program for someone from nearly any discipline. In fact, during an informal walk-around here at the Missoula Fire Sciences Laboratory, I tallied over 30 disciplines or working titles among our staff, distributed among the more general categories of physical science, computing and analysis, engineering, natural sciences, science delivery, and program administration. I celebrate this diversity of knowledge and thought.

In this Annual Report for 2017, we proudly present our progress and outcomes from research and activities aligned under our Six Research Focus Areas—Physical Fire Processes, Fuel Dynamics, Smoke Emissions and Dispersion, Fire Ecology, Fire and Fuel Management Strategies, and Science Synthesis and Delivery. We also highlight our highly impactful Fire Modeling Institute (FMI)—a center of expertise that supports fire and fuels management planning, resource management, and science implementation locally, regionally, nationally, and internationally. A long-standing Team within FMI is dedicated to the operations, maintenance, updating, and modernization of our Fire Effects Information System (FEIS), and we are pleased to present some extraordinary statistics on customer use, which includes over 14,000 FEIS webpage visits.
Outcomes from FMI as well as from our core Research Focus Areas are often developed or integrated into applied products (e.g. databases, tools, applications, systems), and this annual report presents details on ten such applications and products. Our outreach and conservation education continue to grow in both extent and impact. You’ll see in this report how we’ve had direct, organized contact with over 1,900 students and 650 adults in 2017—a 180% increase over 2016!

Wildland fire research is both needed and applied globally, and measurable progress cannot be achieved without strong collaborations with many partners. We are incredibly fortunate to work collaboratively with local, national and international partners to improve wildland fire research activities and outcomes. We offer examples of these partnerships and successes in this report. Our international partnerships have included “boots on the ground” in over 20 countries, including many long-term relationships, science exchanges, consultations, and science delivery activities.

Closer to home are the many Universities and institutions with whom we share dozens of research projects, personnel, and resources. As we note in the section of this report on Partnerships, there are also several unique, formal, long-term partnerships we enjoy. I am particularly proud that, in 2017, we established a permanent position in-residence at Salish Kootenai College (SKC) on the Flathead Indian Reservation in Pablo, Montana. As the only tribal college in the US that provides a 4-year Forestry degree program, SKC is an ideal host for this Liaison Officer position. SKC is receiving increasing levels of recognition as a leader in educating the next generation of Native American foresters and is seeking accreditation through the Society of American Foresters. SKC student enrollment hovers around 800 with approximately 71% of the population as enrolled tribal members or descendants from 70 different tribes. Dr. Serra Hoagland is now our Forest Service Liaison Officer. By having a U.S. Forest Service liaison in residence at SKC, students, faculty and staff at SKC have a direct line of communication with the U.S. Forest Service. This on-site network fosters
collaboration with key staff in the Forest Service. Perhaps more importantly, Dr. Hoagland serves as a role model, mentor, and advisor to tribal students, not just at SKC but for all Tribal Colleges and Universities (TCU) through her extensive outreach and participation in events across the U.S.

While not addressed much in this 2017 Annual Report for the FFS Program, there are two additional units I’d like readers to be aware of. The first, the Wildland Fire Management Research, Development, and Applications Program (WFM RD&A), was created to promote application of wildland fire scientific knowledge; develop decision support tools; and provide science application services to the interagency wildland fire community.” Please visit their website at https://wfmrda.nwcg.gov/ for details and more information. Another significant development and applications group within RMRS and co-hosted by the FFS Program and the RMRS Human Dimensions Program is a very unique “virtual organization” called the National Fire Decision Support Center (NFDSC). The goals of the NFDSC are to build upon previous science achievements that promote and facilitate 1) the development of new fire behavior science and practical prediction tools, 2) strengthen the science of fire management activities and performance, 3) advance the science, development, and dissemination of quantitative wildland fire risk analysis methods. As noted in the “charter” for NFDSC, overlap and interaction of the NFDSC with the WFM RD&A and the Fire Modeling Institute is critical to the practical implementation of science products.

Our Program’s science is frequently featured in the media, with coverage ranging from local to international. The Missoula Fire Sciences Laboratory was deliberately located in Missoula, and adjacent to the airport, to exploit the critical mass of regional and national wildland fire facilities and activities. These currently include the Northern Rockies Coordinating Center, The Missoula Smokejumper Base, the Aerial Fire Depot, a regional Fire Cache, National Technology and Development Program (NTDP), and the National Weather Service. Not surprisingly, this critical mass attracts significant media attention, and we certainly do
benefit. In addition, of course, is the attention our science garners in its own right. We have several scientists in the Program who have offered over 50 interviews in less than a year—in one case, based solely on a single publication! This attention and outreach helps considerably in our mission to deliver science to users and the public.

In what I believe is a true “highlight of highlights” of our accomplishments for 2017, we describe the revival of a study begun in 1970 that led to the first Prescribed Natural Fire (PNF) in Forest Service wilderness—the White Cap study and subsequent Bad Luck Creek Fire in 1972. In early fall of 2017 we hosted a reunion for many of the original principals of that study, on site at a campground in the Whitecap drainage. I am proud and honored that we can offer the story of this reunion and subsequent re-measurement campaign in this report.

Colin Hardy, Program Manager

Colin Hardy, Program Manager. Photo courtesy of Colin Hardy
The Fire Modeling Institute’s (FMI) mission is to connect and support managers, scientists, and the public in addressing fire and fuels management and education needs, using the best fire science and technology available, current information from scientific literature, and appropriate science delivery methods.

FMI is a joint effort between the Fire, Fuel, and Smoke Science Program (FFS) of the Rocky Mountain Research Station and Washington Office Fire and Aviation Management (FAM). It is a center of expertise that supports fire and fuels management planning, resource management, and science implementation locally, regionally, nationally, and internationally. FMI operates in six primary areas:

- **Analysis and Support.** FMI scientists perform technical analyses in support of a wide range of projects, including fire behavior and fire effects modeling and spatial data analyses.
- **Applied Science.** FMI scientists seek out opportunities to apply the latest fire science research to management needs at all scales.
- **Data Development and Stewardship.** FMI scientists develop and maintain data in support of national-scale products supporting the fire community.
- **Science Synthesis and Delivery.** FMI scientists synthesize and deliver fire science information for practitioners in the field. This includes the technological transfer of FFS science, and the integration and synthesis of fire science from all sources.
- **Software Application Management and Subject Matter Expertise.** FMI scientists maintain, enhance, and serve as the subject matter experts for FFS software applications and products, and work to integrate FFS applications, application data, and FFS science into non-FFS applications. Applications include BehavePlus, FARSITE, FEAT-FIREMON Integrated (FFI), the Fire Effects Information System (FEIS), FireFamilyPlus, The First Order Fire Effects Model (FOFEM), FlamMap, FuelCalc, and the U.S. National Fire Danger Rating System (NDFRS), which includes the Weather Information Management System (WIMS) and the Wildland Fire Assessment System (WFAS).
- **Training and Education.** FMI scientists provide a wide range of training and education opportunities to facilitate the understanding, adoption, and application of fire science research by field practitioners and the general public.

Initially chartered in 2001, FMI had their charter renewed in 2017, extending the partnership between FAM and RMRS through 2021. Staff and contributors to FMI are Thomas Dzomba (FMI Director), Ilana Abrahamson (FEIS Lead), Larry Bradshaw, Greg Dillon, Janet Fryer, Duncan Lutes, Faith Ann Heinsch, LaWen Hollingsworth, Robin Innes, Matt Jolly, Ashley Juran, Eva Karau, Eva Masin, Chuck McHugh, Shawn McKinney, Shannon Murphy, Matt Panunto, Kris Zouhar.
Fire Effects Information System (FEIS)

Thousands of scientific articles and reports are published each year on wildland fire, making it difficult for managers, planners, and scientists to find, read, and use the best available science. As part of the FMI group, FEIS is a team of ecologists that synthesizes this information and publishes new and updated syntheses online in the Fire Effects Information System (FEIS), so managers can easily find and better apply science to land management decisions. FEIS offers four peer-reviewed publication types: Species Reviews, Fire Regime Syntheses, Fire Regime Reports, and Fire Studies:

- **Species Reviews** are syntheses of the published literature covering the biology, ecology, and fire effects on plants and animals in the United States. This year, FEIS ecologists continued to update Species Reviews, and focused on high-concern species that managers requested, such as mountain big sagebrush and the nonnative annual grass ventenata.

- **Fire Regime Syntheses** integrate LANDFIRE data with information from the scientific literature to provide in-depth information on historical fire regimes and address contemporary changes in fuels and fire regimes. Fire Regime Syntheses published in 2017 cover: ponderosa pine communities in the Black Hills and surrounding areas, conifer forests in the Blue Mountains, Alaskan mountain hemlock ecosystems, and Alaskan Pacific maritime ecosystems.

- **Fire Regime Reports** summarize and facilitate access to LANDFIRE data, however they do not include syntheses of the scientific literature. Both Fire Regime Syntheses and Fire Regime Reports connect LANDFIRE data to all of the 1,083 Species Reviews in FEIS. Through Fire Regime Syntheses and Reports, FEIS contains fire regime information for all of the plant communities in the United States.

- **Fire Studies** are summaries of one or more fire research projects at a specific location. They provide detailed descriptions of site characteristics, burning conditions, fire behavior, and fire effects. They complement Species Reviews and provide information on hundreds of species for which a Review is not available. This year, two Fire Studies were updated and published.

All FEIS publications provide a wealth of information for land managers, with applications in fuels and fire management and postfire restoration. FEIS is used by managers in federal land management agencies, states, tribal lands, nongovernment conservation organizations, as well as private land owners, university students and scientists, and the general public. In 2017, FEIS had at least 7,000 users who were employed by federal agencies; more than 4,500 were employed by USDA, and more than 2,600 were employed by USDI. In FY17, Forest Service users visited over 14,000 FEIS webpages, potentially saving them hundreds of hours by using FEIS syntheses rather than doing the literature review on their own.
Partnerships

Developing partnerships and creating cross-disciplinary research teams are critical in addressing the growing number of increasingly complex questions related to wildland fire. Fire, Fuel, and Smoke Science Program researchers and professionals at the Missoula Fire Sciences Laboratory work collaboratively with national and international partners to improve wildland fire research that maintains healthy, productive ecosystems and reduces risk to people and property. The summaries in this report include collaborations with other federal agencies, tribes, state and local governments, universities, and non-governmental organizations.

In 2017, FFS investigators collaborated with diverse teams of researchers at over a dozen universities around the country as well as with other federal agencies including the Bureau of Land Management, Bureau of Indian Affairs, Department of Defense, Environmental Protection Agency, National Aeronautics and Space Administration, and U.S. Agency for International Development. Nationally, FFS researchers collaborated with scientists from Arizona to Florida and from the Appalachians to the Cascades to better understand a range of topics, including physical fire processes, fuel dynamics, smoke emissions, fire and fuel management treatment strategies, and fire ecology. Science professionals in the Fire Modeling Institute (FMI) worked with multiple partners providing geospatial analyses in support of community wildfire risk planning in Bemidji MN, Chelan County WA, and Missoula County MT. For example, the Community Wildfire Protection Plan (CWPP) recently approved and adopted by Missoula County Board of Commissioners relied heavily on the spatial risk assessment mapping and analyses performed by our FMI staff. This project was a model for how FS science providers can partner with local governments as well as with NGO’s such as Headwaters Economics in the true spirit of the Wildland Fire Management Cohesive Strategy, and has led to numerous other complementary partnerships in the region—all are examples of co-production, or “all-hands, all-lands.”

Partnerships combine each member’s strengths to produce more effective and far-reaching research and to develop and deliver new tools and scientific understanding. We are formally engaged with the work of the Northern Rockies Fire Science Network (a member of the Joint Fire Science Program fire science exchange network), and we have benefitted from long-term agreements with both University of Montana and University of Idaho fire science and technical transfer partners. The long-term partnership we’ve enjoyed with the University of Montana’s National Center for Landscape Fire Analysis (“Fire Center”) has enabled both organizations to leverage one another’s strengths as well as complementing our unique, respective niches. Together, we continue to develop, synthesize, and deliver scientific products, applications, and geospatial technology to improve fire and fuels management. Similarly, our long-term partnership with University of Idaho supports two highly-valued outcomes: 1. development of fire science professionals and collaborations; and 2. operations and maintenance of the Fire Research and Management Exchange System (FRAMES) to make wildland fire tools, information and other resources easy to find, access, distribute, compare, and use.

Our program works closely with faculty and staff at Salish Kootenai College (SKC) — one of the four largest Tribal Colleges and Universities (TCUs) in the nation — as well as with tribal
forestry at Confederated Salish and Kootenai Tribes to enhance connections between traditional knowledge and western science. We now host a permanent, fulltime, Forest Service research professional who serves as our “liaison officer” with SKC, working and located “in residence” at SKC. This liaison position at SKC links internationally recognized natural resource professionals with tribes to support the understanding of various impacts of forest restoration to maintain healthy, resilient forests. The position also meets numerous objectives related to youth development/outreach, technology transfer and objectives outlined in the U.S. Forest Service Tribal Engagement Roadmap.

Internationally, FFS researchers and science professionals have developed partnerships with colleagues from nearly every continent. International partnerships take advantage of the FFS Program’s scientific expertise, technological capability, and on-the-ground experience in fire ecology, fire climatology, and fire management. The FFS Program has had “boots on the ground” in over 25 countries, as illustrated by our map of International partners presented on our webpage at http://www.firelab.org.

For more information, contact: Colin Hardy at chardy01@fs.fed.us.
Laboratory studies and theoretical physical modeling, informed and validated by field observations, are used to examine physical fire processes and improve our capability to manage fire safely. This research is designed to improve understanding of the fundamental, multi-scale, physical processes that govern fire behavior, including combustion processes, heat and energy transfer, atmospheric dynamics, and transitions from one type of fire behavior to another. Scientists analyze the combustion process and the factors that determine fire behavior with the goal of developing a comprehensive physics-based fire modeling system that includes the full range of combustion environments and fire events observed in wildland fuels. New physics-based understanding will be incorporated into models suitable for use by fire and fuels managers both for characterizing fire danger and predicting fire behavior. Scientists need to model fire behavior for a wide range of purposes including improving firefighter safety, simulating site-specific vegetation, predicting loss of life or property, and global carbon accounting.

### Improving firefighter safety

How studies of energy transport are improving wildland firefighter safety zone guidelines.

Wildland firefighting by its nature is inherently dangerous. There have been 699 wildland firefighters die in fire related accidents between 1910 and 1996 in the United States; 384 of those were directly related to fire entrapments. Wildland firefighters must consider all risks to themselves and others when approaching, suppressing, and managing wildland fire, and then take appropriate action to minimize those risks.

One of the critical decisions made by fire fighters on any wildland fire is the identification of suitable safety zones; areas where firefighters can safely wait for the fire to burn around them. The term “safety zone” first appears in official literature in the United States in the aftermath of the Inaja fire where 11 firefighters were killed and the United States Forest Service issued a report that highlighted the need for better training and recommended that all firefighters identify safety zones at all times when fighting fire. The United States Forest Service defines a safety zone as “a preplanned area of sufficient size and suitable location that is expected to protect fire personnel from known hazards without using fire shelters”. Safety zones should be available and accessible in the event that fire behavior or intensity increases suddenly making current suppression tactics unsafe.
Current efforts are focused on finalizing a new algorithm based on direct measurements of energy transport in laboratory and field experiments as well as modeling of energy transport using sophisticated combustion models. The results developed so far suggest that the currently developed and published physics based safety zone models are adequate for flames larger than 10 m but for shorter flames wind and slope have significant impacts on the energy and heating environment. The implications are that in some cases safety zones must be much larger than previously thought. This implies that adequate safety zones may require significant impact on the landscape or other mitigating measures must be taken to protect life.

**Focus Areas:** Physical Fire Processes, Smoke Emissions and Dispersion

*For more information, contact:* Bret Butler at bwbutler@fs.fed.us

---

Convective Ignition

**Convective Ignition of Forest Fuels**

Recent research conducted at the Missoula Fire Lab has found that the amount of radiant heat in wildland fires is not sufficient to ignite fine fuel particles such as needles and grasses. These fine fuels are highly efficient at convective heat transfer, so any amount of airflow can easily offset the radiant heat generated by the fire. As a consequence, fine wildland fuels do not ignite until bathed by the flame. As radiant heating has been assumed to drive ignition in wildland fires as it does in structural fires, ignition by convective heating is not well understood.

Experiments are underway to determine if and how ignition due to convective heating is different than that from radiative heating. We built an apparatus using two electrical heaters to heat air up to 1200°C (2200°F). So far, wood cylinders and disks of different diameters and thicknesses have been tested. A simple model has been shown to predict the ignition times of these simple fuels with reasonable accuracy. Several differences between convective and radiative heating have been noted. For example, the convective heating and ignition process is far more sensitive to fuel size and shape than radiative heating. Another major difference between these modes of ignition is the large surface temperature gradient that forms due to convective heating that is largely missing under radiant heating.

Understanding the ignition process due to convective heating will allow for better prediction of the transition from surface to crown fire and crown fire spread, two aspects of wildland fire behavior that are largely misunderstood.

**Focus Areas:** Physical Fire Processes

*For more information, contact:* Sara McAllister at smcallister@fs.fed.us

---

Ignition of ¼"-diameter rod in 800 °C air. Time between frames was 17.7 ms. Photo by: Sara McAllister
Burning rate

Understanding Burning Rate and Residence Time of Porous Fuel Beds Using Wood Cribs

Flame residence time is critical to the spread of wildland fires; if it is less than the ignition time, the fire won’t spread. Although even surface fires demonstrate spread thresholds, this is of particular concern when discussing the thresholds for crown fire spread, a currently poorly understood aspect of wildland fire. Curiously, no single theory exists for the prediction of flame residence time. Expressions in the literature vary from linear to quadratic dependence of flame residence time on fuel thickness. Better understanding of flame residence time and burning rate of fuel structures will allow for better fire spread and fire effects predictions.

Research Mechanical Engineer Sara McAllister studied the burning rate of fuel structures to better understand residence time using three-dimensional grids of sticks called cribs, commonly used in the fire protection engineering (structural fire) literature. Cribbs were built with different stick thicknesses and densities to vary the burning rate of the source fire. Even though wildland fuels do not have the same predictable arrangement as cribs, wildland fuels are similar to cribs in that they are essentially individual fuel particles arranged with some spacing distance between them. Thus, the fundamental understanding of what governs the burning rate of a crib would apply to the wildland fire context.

Burning rates of cribs with a wide variety of layouts and geometries were explored to determine whether the knowledge gained from the field of structural fire holds in the wildland context. Comparisons included the effect of stick dimension (length and width) ratios and the effect of spacing distance between the crib and the support platform. Cribbs tested with geometries similar to those tested in literature matched predicted values well. However, the burning rate of cribs built with sticks of large length-to-thickness ratios (such as long, thin sticks) was considerably lower than predicted, indicating that there is insufficient airflow inside the crib not predicted by current models. The effect of spacing distance between the crib and the support platform was strongly dependent on the stick length-to-thickness ratio, with no difference seen for cubic cribs and a >60 percent change for cribs with large stick length-to-thickness ratios. Experiments indicated that cribs with large length-to-thickness ratios required a substantial amount of airflow through the bottom of the crib. As the crib-platform spacing increased, however, the burning rate of the large length-to-thickness ratio cribs increased to more closely match the predicted values. The effect of other environmental variables, such as the presence of wind and a chimney effect, are also being explored.

Focus Areas: Physical Fire Processes

*For more information, contact:* Sara McAllister at smcallister@fs.fed.us

Various burn methods. Photo by: Sara McAllister
3D Fuel and Fire Modeling
Seeing the forest for the trees: expanding fuel and fire modeling to 3D provides a stronger basis for evaluating fuel treatments

Fuel treatments such as thinning operations offer a means to proactively mitigate risks to firefighters and communities, and to restore altered ecosystems. While traditional thinning approaches tend to produce fairly homogeneous conditions, in recent years there has been increasing interest in fuel treatments that modify forest spatial patterns, producing patchy or clumpy fuel patterns with variable species and size distributions. Such fuel spatial heterogeneity is considered to be an important characteristic contributing to the long term resilience of forest ecosystems in the face of numerous disturbance processes, such as fire, insects and disease.

To better understand how forest structure, composition and spatial pattern, as well as other disturbances such as beetle attacks, may affect fire behavior and effects, we have been working on a prototype 3D fuel and fire modeling platform, called STANDFIRE. STANDFIRE connects a widely used forest model, the Forest Vegetation Simulator (FVS) to 3D physics-based fire behavior models, enabling very detailed fire modeling that is sensitive to the spatial arrangement and specific characteristics of individual trees within a forest stand.

For researchers who have stem mapped or LiDAR mapped forest research plots, STANDFIRE can be used with real world coordinates. In the more common case where users do not have spatially explicit data (ie, coordinates of trees are not known) STANDFIRE statistically models representative forests based on inventory data. In either case, STANDFIRE can be used to compare fire behavior and effects between different treatment scenarios or to test effectiveness of fuel treatments in different conditions.

STANDFIRE is a working prototype system, significant in that it opens the door to new approaches for analyzing how forest changes, either over time, through management activities or other disturbances, affect fire behavior and fire effects. In its current state STANDFIRE will be of use to a broad range of practitioners. As a prototype system, however, it should be considered as a work in progress. We hope to continue developing and building new capabilities for many years to come.

Focus Areas: Fuel Dynamics
For more information contact: Bob Keane at rkeane@fs.fed.us
Reconstructing U.S. Wildland Fire Trends

Assessing the impact of changing fire weather conditions on reconstructed trends in U.S. wildland fire activity

The ecological, economic and health and safety concerns surrounding wildland fires are driving the need to better understand climate-fire interactions. One component of climate-fire interactions is the relationship between weather conditions concurrent with burning (i.e., fire danger) and the magnitude of fire activity. To date most relationships have been developed using monthly or seasonally averaged fire danger indexes and total accumulated burned area. This project extends and resolves these relationships by synchronizing a daily gridded fire danger climatology with daily satellite observations of fire activity collected with the Moderate Resolution Imaging Spectroradiometer (MODIS). Results reveal that modern relationships (2003 – 2014) between fire danger and fire activity vary regionally, but in general, fires across the majority of the continental U.S. (CONUS) are more likely to be present and burning more vigorously as fire danger increases. Applying modern relationships to the entire climatology (1979 – 2014) indicates that changes in fire danger have significantly increased the number of days per year that fires are burning across 42 - 49% of CONUS (by area) whilst also significantly increasing daily fire growth and the daily heat released by fires across 37 – 45% of CONUS. Increases in the fire activity season length coupled with an intensification of daily burning characteristics resulted in a CONUS-wide +0.02 Mhayr-1 trend in burned area, a +10.6 g m-2 yr-1 trend in the amount of fuel consumed per unit burned area, and ultimately a +0.51 Tgyr-1 trend in dry matter consumption. Overall this project has found that synchronizing spatially resolved fire danger indices with satellite observations of fire activity offers opportunities to develop modern associations between daily environmental conditions and daily burning characteristics. Moreover the application of modern associations provides a pathway for both reconstructing as well as forecasting changes in regional fire occurrence and burning characteristics solely from changes in fire danger.

**Focus Areas:** Physical Fire Processes, Smoke Emissions and Dispersion

*For more information, contact: Patrick Freeborn at patrickhfreeborn@fs.fed.us*
Fuel Dynamics

Research on fuel dynamics helps land managers describe the vegetation that burns during wildland and prescribed fires. FFS scientists investigate and design consistent, accurate, and comprehensive methods for quantifying wildland fuels, which vary spatially, differ in size, and change with time. Through laboratory and field studies, FFS scientists are developing tools to predict seasonal and multi-year changes in fuels that allow managers to more accurately predict fire behavior and fire effects. Improved data for fire behavior modeling and fuel hazard assessment and improved fuel dynamics algorithms for temporal models of fire behavior, fire danger, and fire effects are critical additions for the next generation of fire models.

Live Fuels and Fire Behavior Research

Exploring linkages between live wildland fuels, ignition, combustion and potential fire behavior

Wildland fires are a common global ecosystem disturbance and they spread through a combination of living and dead vegetation. Historically, research on fuel ignition and fire behavior characteristics has focused on dead fuels that are easily manipulated in the field and laboratory. However, live fuels represents a large part of the wildland fuel complex and little is known about the key factors that drive their inter- and intra-species variations in flammability.

Scientists at the Missoula Fire Sciences Laboratory, in partnership with various regional and global partners, are continually developing and refining studies that examine the complex relationships between fuel moisture, chemistry, physical and thermal characteristics that can influence live wildland fuel ignition, spread rates and intensities. Our work spans a range of methods from small-scale benchtop experiments in the laboratory to large-scale field prescribed burns. Additionally, in partnership with researchers at Los Alamos National Laboratories, we leverage computational fluid dynamics-based fire behavior simulators to create controlled numerical experiments to explore these complex interactions.

This work is leading to entirely new conceptual models that describe these complex linkages in ways that can be directly integrated into fire danger and fire
behavior modeling systems.

Focus Areas: Fuel Dynamics, Physical Fire Processes

For more information, contact: Matt Jolly at mjolly@fs.fed.us

Fuel PArtile DYnamics (FPARDY)

Documenting surface fuel layer and particle properties in forests of the US northern Rocky Mountains to create the next generation of wildland fuel applications

The research project presented here, labeled FPARDY (Fuel PArtile DYnamics), is one of many new efforts to explore surface fuel characteristics at the particle, layer, and fuelbed levels across major forest ecosystem types in the US northern Rocky Mountains (NRM) to develop a set of products that integrate these findings into standard fuel applications. First, we will select stands that are representative of NRM forest vegetation types in composition and structure. We will then measure many fuel properties in situ using a nested sampling design. We will then collect some of the fuels and bring them back to the lab to measure many other physical and chemical characteristics. Once we have the physical and chemical characteristics of the particle, layer and fuelbed as a whole, we will then explore any relationships that can be detected by correlating management-oriented variables, such as loading, to a suite of other variables computed at the three scales in this study. We will also use using advanced statistical clustering and modeling to explore new ways of classifying and sampling fuels based on loadings. After we have thoroughly explored all possible relationships, we will start the development of new methods, protocols, technology, and applications for wildland fuel management. At a minimum, we will develop new sampling methods and new classifications for wildland fuels, and produce guidebooks on how to assign fuel characteristics to wildland fuelbeds.

The FPARTY project has one primary objectives and a number of specific objectives:

- Explore the structure, composition, and properties of surface and canopy fuelbeds in NRM forests

This objective can be achieved using the following steps described as sub-objectives;

- Measure fuelbed properties in situ at the particle, layer, and fuelbed scales for major forest types of the northern Rocky Mountains
- Collect all fuel particles from fuelbed for further laboratory analysis to determine a set of fuel particle properties that are important in fuel description, fire modeling, and fuel sampling
- Perform statistical analysis to explore A typical microplot from the FPARDY study before the woody material and vegetation is removed for lab sampling. Photo by: Bob Keane
relationships of measured particle properties to loading by fuel component.

- Develop a set of deliverables that synthesizes the findings of the fuels exploration into management guides, protocols, and technology.

The audience for this effort is managers and researchers interested in describing and sampling fuels for fire behavior and effects prediction. This research may lead to new methods of simplifying fuels characteristics to aid fuel mapping efforts. Moreover, it should provide important parameters and values for fuel sampling efforts.

Focus Areas: Fuel Dynamics
For more information contact: Bob Keane at rkeane@fs.fed.us.

Photoload

A new fuel loading sampling method is developed to quickly and accurately estimate loadings for six surface fuel components using downward-looking and oblique photographs depicting sequences of graduated fuel loadings by fuel component.

Fire managers need better estimates of fuel loading using techniques that are easy, fast, and reliable so they can more accurately predict the potential fire behavior and effects of alternative fuel and ecosystem restoration treatments. A new fuel sampling method, called the photoload sampling technique, has been developed to quickly and accurately estimate loadings for six common surface fuel components (1 hr, 10 hr, 100 hr, and 1000 hr down dead woody, shrub, and herbaceous fuels). This technique involves visually comparing fuel conditions observed in the field with photoload photographs depicting a sequence of graduated fuel loadings of synthetic fuelbeds for each of the six fuel components. This research as created a report that contains a set of photoload sequences that describe the range of fuel component loadings for common forest conditions in the northern Rocky Mountains of Montana, USA to estimate fuel loading in the field. A detailed sampling method, called the photoload sampling protocol, has also been developed to use with these photoload picture series to estimate fuel component loadings at various levels of effort and scale. This technique has been compared with other common fuel loading sampling methods for accuracy and precision.

Focus Areas: Fuel Dynamics
For more information contact: Bob Keane at rkeane@fs.fed.us.
Ponderosa Pine Restoration at Lick Creek

Lick Creek Demonstration-Research Forest: 25-year fire and cutting effects on vegetation and fuels

The Lick Creek Demonstration/Research Forest (Lick Creek) on the Darby Ranger District of the Bitterroot National Forest, MT provides a unique opportunity to assess 25-year-effects of burning and cutting restoration treatments. In 1991, a cooperative venture among the Bitterroot National Forest, University of Montana, and Forest Service Intermountain Research Station (now Rocky Mountain Research Station) initiated a new research experiment with seven prescribed burning and cutting treatment variants to test restoration alternatives in restoring the site’s ponderosa pine vegetation community and reduce fuel loads to historically-appropriate levels. Silvicultural treatments were implemented in 1992, followed by prescribed burning in 1993 and 1994, under a fully replicated experimental design involving randomization of treated units and a permanent, systematic plot sampling network.

The goals of the initial project were to increase knowledge of forest vegetation and fuel dynamics following restoration treatments, study how these differ among restoration treatment alternatives, and gain understanding of the efficacy and longevity of prescribed treatments. Study results have provided managers with guidelines for restoring ponderosa pine systems in the northern Rocky Mountain region. In 2015 the Joint Fire Science Program funded a re-measurement of the Lick Creek study plots. This new work will result in many benefits, including:

- Complete 25-year (1991-2016) effects of seven silvicultural cutting and burning treatments on fuels and vegetation.
- Archived data with complete documentation of study protocols to encourage future data analysis.
- Demonstration site that is easily accessible to a large population center to communicate forest restoration and management treatment results to both the public and managers.
- Photo-history of the effects of fire exclusion and restoration treatments from 1909 – 2016. In addition, re-measurement would give added value to past data collection through modern data analysis techniques to examine treatment effects on aspects of forest resilience, including:
  - Resistance to bark beetle outbreaks: Mountain pine beetle populations are currently high on the Bitterroot National Forest (Egan et al. 2013), providing a unique opportunity to directly test treatment effects on resistance to bark beetles, a natural

![Mick Harrington describes Lick Creek treatments to a visiting group. Photo by: Duncan Lutes](image)
disturbance enhanced by warming and drought associated with climate change. This is possible because we have past censuses of tree mortality causes through 2005. We will combine these results with similar studies of mid-term treatment effects in the region (Hood et al. In Prep) to help inform how management actions impact forest resistance to bark beetles.

- Resilience from drought: We will apply newly developed methods (Lloret et al. 2011) to quantify tree resilience from drought in the different treatments. This novel method has already been advocated as a very promising resilience metric for use in the Sierra Nevada (North and Stine 2012).

- Resilience from wildfire: Potential fire behavior using canopy fuel loading and different weather scenarios has never been simulated for Lick Creek. Methods to quantify canopy fuels were not available at the time the study was established, but all required data to calculate canopy fuels were collected. Re-measurement will allow us to assess differences in fire hazard among treatments over time using modern fire behavior systems (e.g., BehavePlus, FFE-FVS, Nexus) with real surface, canopy, and vegetation data as inputs to models.

- Treatment longevity and successional trajectories: Ten-year physiological responses to treatments reported in Sala et al. (2005) indicated that trees in the cutting and burning treatments had less water stress and faster growth compared to trees in the control treatment. Re-measurement will allow us to assess the degree to which treatment-specific differences in vegetation characteristics have changed over time. More sophisticated multivariate analyses techniques are now available that allow incorporation of both vegetation and fuel variables to examine the successional trajectories of

![Photo documentation of stand changes. Photos collage by: Sharon Hood](image-url)
Fuel treatment impacts in ponderosa pine - Douglas-fir forests in the Northern Rockies

Fire frequency in low-elevation coniferous forests in western North America has greatly declined since the late 1800s. In many areas, this has increased tree density and the proportion of shade-tolerant species, reduced resource availability, and increased forest susceptibility to forest insect pests and high-severity wildfire. In response, treatments are often implemented with the goal of increasing ecosystem resilience by increasing resistance to disturbance. We capitalized on an existing replicated study of fire and stand density treatments in a ponderosa pine (Pinus ponderosa)-Douglas-fir (Pseudotsuga menziesii) forest in western Montana, U.S. that experienced a naturally occurring mountain pine beetle (MPB; Dendroctonus ponderosae) outbreak five years after implementation of fuels treatments. We explored whether treatment effects on tree-level defense and stand structure affected resistance to MPB. Mortality from MPB was highest in the denser, untreated control and burn-only treatments, with approximately 50% and 39%, respectively, of ponderosa pine killed during the outbreak, compared to almost no mortality in the thin-only and thin-burn treatments. Thinning treatments, with or without fire, dramatically increased tree growth and resin ducts relative to control and burn-only treatments. Prescribed burning did not increase resin ducts, but did cause changes in resin chemistry that may have affected MPB communication and lowered attack success. While ponderosa pine remained dominant in the thin and thin-burn treatments after the outbreak, the high pine mortality in the control and burn-only treatment caused a shift in species.

Examples of each treatment 15 year after treatment. In the control, where no treatment occurred, mortality from mountain pine beetle was high. In the burn-only treatment, mortality from mountain pine beetle was slightly lower than the control. Mountain pine beetle killed very few trees in the thin-only and thin-burn treatments. Note the high level of Douglas-fir seedlings in the thin-only compared to the thin-burn treatment.
dominance to Douglas-fir. The high Douglas-fir component in the control and burn-only treatments due to 20th century fire exclusion, coupled with high pine mortality from MPB, has likely reduced resilience of this forest beyond the ability to return to a ponderosa pine-dominated system in the absence of further fire or mechanical treatment. Our results show treatments designed to increase resistance to high-severity fire in ponderosa pine-dominated forests in the Northern Rockies can also increase resistance to MPB, even during an outbreak. This study suggests that fuel and restoration treatments in fire-dependent ponderosa pine forests that reduce tree density increase ecosystem resilience in the short term, while the reintroduction of fire is important for long-term resilience.

Focus Areas: Fuel Dynamics, Fire and Fuel Management Strategies, Fire Effects

For more information, contact: Sharon Hood at sharonmhood@fs.fed.us
Smoke Emissions and Dispersion

Officials charged with supporting public health and safety need better tools to estimate effects of wildfire on smoke emission levels, visibility standards, and carbon budget applications as well as to anticipate the movement of smoke across the country and around the globe. FFS researchers are developing and testing methods for implementing a real-time emissions inventory and dispersion models for smoke emissions from wildland fires. Researchers are integrating field observations, satellite data, and smoke chemistry with models of emissions, smoke composition, and movement either within a fire plume or through layers of the atmosphere to improve understanding and prediction of smoke emissions and dispersion. This work applies to issues relating to National Ambient Air Quality Standards under the Clean Air Act, regional haze issues, and continental and global climate change questions.

Missoula Fire Lab Wildfire Emission Inventory

The Missoula Fire Lab Emission Inventory (MFLEI) is a retrospective, daily wildfire emission inventory for the contiguous United States with a spatial resolution of 250 meters (m). MFLEI was produced using multiple datasets of fire activity and burned area, a newly developed wildland fuels map and an updated emission factor database.

Wildfires are a major source of air pollutants in the United States. Wildfire smoke can trigger severe pollution episodes with substantial impacts on public health. In addition to acute episodes, wildfires can have a marginal effect on air quality at significant distances from the source presenting significant challenges to air regulators’ efforts to meet National Ambient Air Quality Standards (NAAQS) and improve visibility in National Parks and Wilderness Areas as required under the federal Regional Haze Rule. Improved emission estimates are needed to quantify the contribution of wildfires to air pollution and thereby inform decision making activities related to the control and regulation of anthropogenic air pollution sources.

To address the need of land managers and air regulators for accurate wildfire emission estimates the Fire, Fuel, and Smoke Program’s Smoke Emission and Dispersion Team developed the Missoula Fire Lab Wildfire Emission Inventory (MFLEI), a retrospective, daily wildfire emission inventory for the contiguous...
United States. MFLEI was produced using multiple datasets of fire activity and burned area, a newly developed wildland fuels map and an updated emission factor database. The fuel type classification map is a merger of a national forest type map, produced by the USFS Forest Inventory and Analysis (FIA) program and the Remote Sensing Applications Center (RSAC), with a shrub and grassland vegetation (rangeland) map developed by the USFS Missoula Forestry Sciences Laboratory. Forest fuel loading is from a fuel classification developed from a large set (> 26,000 sites) of FIA surface fuel estimates. Herbaceous fuel loading is estimated using site specific parameters with Normalized Differenced Vegetation Index (NDVI) from the Moderate Resolution Imaging Spectroradiometer. Shrub fuel loading is quantified by applying numerous allometric equations linking stand structure and composition to biomass and fuels. These structure and composition data are derived from canopy cover, canopy height, and species composition data from the LANDFIRE Project.

The MFLEI provides estimates of daily wildfire pollutant emissions at a 250 m x 250 m resolution for 2003-2017. Figure 1 compares June – September fine particulate matter (PM2.5) emitted by wildfires with anthropogenic sources (from EPA data) across the western U.S. The figure shows that in most years, wildfire emissions of PM2.5 far exceed the amount produced by anthropogenic sources (e.g. transportation, power generation, industrial processes, and agriculture). Phase 2 of this project will combine daily emission estimates from MFLEI with measurements of pollutant concentrations from state air quality monitoring networks to evaluate air quality forecasting models. Figure 2 maps the perimeters of several fires active in the Northern Rockies during August 17 – 31, 2017 and the location of four cities heavily impacted by smoke during this period. The line plots show daily average PM2.5 concentrations measured at four Montana Department of Environmental Quality monitor sites. The dashed lines in the plots denote the 24 hour NAAQS for PM2.5 (35 µg m

---

**Focus Areas: Fire Effects, Smoke Emissions and Dispersion**

For more information, contact:
Shawn Urbanski at surbanski@fs.fed.us
Impacts of wildfire emissions on Salt Lake City

Impacts of upwind wildfire emissions on CO, CO2, and PM2.5 concentrations in Salt Lake City, Utah

Fine particulate matter, also called PM2.5, is an air pollutant with significant public health impacts that is regulated under the federal Clean Air Act and is the primary air pollutant of concern across much of the western United States. PM2.5 pollution has many sources: industrial and agricultural activities, power generation, transportation, and construction. In addition to these anthropogenic sources, wildfires are a major source of PM2.5. In contrast to anthropogenic sources, pollution from wildfires is sporadic, intense, and may impact urban areas 100’s to 1000’s of kilometers downwind. State agencies are tasked with developing emission control strategies to minimize public exposure to PM2.5 and maintain compliance with federal air quality standards. The development of effective and efficient emission controls for anthropogenic sources requires quantitative knowledge of the contribution of wildfires to air pollution in population centers.

A collaborative project between the RMRS Fire, Fuel, and Smoke Program’s Smoke Emission and Dispersion research team and researchers from the University of Utah sought to quantify the contribution of wildfires to pollution in Salt Lake City, Utah. A new, high-resolution wildfire emission inventory, the Missoula Fire Lab Emission Inventory (MFLEI), was combined with the Stochastic Time-Inverted Lagrangian Transport (STILT) model, an advanced atmospheric model, to quantify the influence of western U.S. wildfires on PM2.5 concentrations in Salt Lake City. The study focused on the active wildfire seasons of 2007 and 2012. To determine the influences of wildfires, an ensemble of back trajectories at the Salt Lake City receptor within the WRF-STILT model were combined with the MFLEI pollutant emissions.

Initial results showed that the WRF-STILT model was able to replicate many periods of enhanced wildfire activity observed in PM2.5 and carbon monoxide (CO) measurements in Salt Lake City. Most of
treatment of smoke plume rise as a weakness in the model and a likely cause of pollution events that were poorly simulated. Based upon the initial study, the plume rise module of the WRF-STILT model is currently being improved. Following the model update, the study will be expanded to include additional urban areas in the west for 2007, 2012, and 2013. When completed, the simulations using the refine model should enable air quality regulators to more accurately account for wildfire contributions to PM2.5 pollution in urban areas.

Focus Areas: Physical Fire, Fuel Dynamics, Fire Effects, Smoke Emissions and Dispersion

For more information, contact: Shawn Urbanski at surbanski@fs.fed.us

Fires in Northern Eurasia

Impacts of Black Carbon from Fires in Northern Eurasia

Northern Eurasia covers 20% of the global land mass and contains 70% of the boreal forest. During certain times of the year, black carbon (BC) in smoke plumes in high latitudes may be transported and deposited on Arctic ice and accelerate ice melting. It is thus imperative to better understand daily sources, transport, and deposition of BC in Northern Eurasia.

We examined daily BC emissions from fires over different land cover types in Northern Eurasia at a 500 m x 500 m resolution from 2002 to 2015. Annual BC emissions from fires varied enormously from 0.39 Tg (1 Tg = 109g) in 2010 to 1.8 Tg in 2003 with an average of 0.7 Tg. BC emissions were dominated by forest fires which accounted for about two-thirds of the emissions, followed by grassland fires (18%). Overall, Russia contributed 80% of the total BC emissions from fires in Northern Eurasia.

August 12, 2014, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Aqua satellite acquired this natural-color image of smoke streaming north over Siberia and then curving eastward in the Arctic. This image illustrates the length of the plume, which stretched from the Sea of Okhotsk to the East Siberian Sea. Image from: http://earthobservatory.nasa.gov/IOTD/view.php?id=84195

Our dataset has been used for studying the transport and deposition of BC on the Arctic from 2002–2013. The study found that approximately 8.2% of the BC emitted by Northern Eurasian fires was deposited on the Arctic ice during the period of
2002–2013, accounting for 45%–78% of the BC deposition from all the sources. About 42% of the BC emitted during spring and summer was deposited on Arctic ice, which is the most effective period for acceleration of ice and snow melting.

These results are critical in understanding the future impacts of climate change on the fire dynamics in Northern Eurasia and the contribution of black carbon to accelerated melting of Arctic ice.

**Focus Areas:** Physical Fire, Fuel Dynamics, Fire Effects, Smoke Emissions and Dispersion

*For more information, contact:* Wei Min Hao at whao@fs.fed.us

**Near Real-Time Burned Area Mapping with VIIRS**

**Development of a Near Real-Time Burned Area Detection Algorithm for VIIRS Sensor on the S-NPP Satellite**

Wildland fires emit significant amounts of greenhouse gases, particulate matter, and ozone precursors which have significant negative effects on public health at multiple scales. In order to mitigate these impacts, state agencies require daily air quality forecasts to minimize exposure risk. Air quality analyses are also necessary to quantify the contribution of fires to regional air pollution and thereby support the development of effective and efficient emission controls for industrial, power generation, and transportation sources. In addition to air quality forecasting and analyses, burned area maps are invaluable tools used by emergency response teams, which often include hydrologists, wildlife biologists, soils scientists, geologists, ecologists, engineers, foresters, botanists, and GIS specialists, and which assess threats to life, property, and natural resources in the days and weeks immediately following a fire. The availability of timely, comprehensive, and consistent burned area estimates can improve fire and forest management decisions and lead to better fire emission estimates and subsequent air quality forecasts and air regulatory strategies.

Currently, the MODIS sensor on the polar-orbiting Terra and Aqua satellites provides burned area products (the satellites’ orbits provide two local overpasses each day - one nighttime and one afternoon). However, the aging MODIS sensors have exceeded their expected lifetime and a

Illustration of the spatial evaluation using the Beaver Creek Fire. The green shaded region is the overlap of the VIIRS and the MTBS burned areas. The blue region is MTBS burned area not detected by the VIIRS algorithm (omission error). The red shading marks regions that were identified as burned by the VIIRS algorithm but not mapped as burned in the MTBS product (commission error). The white regions within the fire perimeter (thick black line) were not mapped as burned by either VIIRS or MTBS.
longer-lasting data solution is needed. The Visible Infrared Imaging Radiometer Suite (VIIRS) sensor onboard the Suomi-National Polar-orbiting Partnership satellite (S-NPP) is the first of the next generation of sensors that will replace MODIS. To address this need a near real-time burned area detection algorithm has been developed for the VIIRS sensor. The algorithm combines VIIRS observations of surface reflectance and thermal anomalies (also called “hot spots” or “active fire detections”) to provide a map of burned area for the western United States shortly after the sensor’s afternoon overpass. The algorithm’s parameters were optimized using Monitoring Trends in Burn Severity (MTBS) annual fire boundaries from 2013 as “ground truth”. The performance of the algorithm was evaluated against MTBS data using the spatial metric “union overlap” as our figure of merit (FOM), as illustrated in Figure 1 for the Beaver Creek Fire (Sawtooth National Forest, Idaho, August 2013). The possible range of FOM is 0 – 1.0, where 1.0 would be perfect overlap between the ground truth and the VIIRS burned areas. Overall, the optimized algorithm performed extremely well with FOM = 0.69 for a combined 212 fire events. Additionally, the overall omission and commission errors were only 15% and 21%.

The USDA Forest Service Remote Sensing Application Center (RSAC) will begin running the VIIRS algorithm operationally for the 2018 western US fire season. The VIIRS based burned area maps will be included as a regular fire support product offered by the RSAC Active Fire Mapping Program. The RMRS Fire, Fuel, and Smoke Program’s Smoke Emission and Dispersion research team will use the VIIRS near real-time burned area to provide daily inventories of pollutant emissions from western wildfire for use in the smoke dispersion and air quality forecasting activities of fire incident air resource advisors, state environmental agencies, and scientific researchers. The timely and comprehensive burned area estimates provided by this new VIIRS algorithm will improve fire and forest management decisions and lead to better air quality forecasts and air regulatory strategies.

**Focus Areas:** Physical Fire, Fuel Dynamics, Fire Effects, Smoke Emissions and Dispersion

*For more information, contact:* Shawn Urbanski at surbanski@fs.fed.us
Fire Ecology

To predict post-fire succession, managers require better understanding of interactions between fire-adaptive traits of plant species and fire severity. They also need improved understanding of treatments, such as prescribed fire with and without harvest, mechanical treatment, and/or herbicide application, and resulting effects on fundamental ecosystem characteristics, such as nutrient cycling, carbon storage, long-term fuel dynamics, and weed invasion. Understanding how treatments interact is important as well. Field and laboratory studies address how fires and, more specifically, the associated heat transfer, fuel consumption, and fire duration, affect plants and plant communities, how fires alter the flow of carbon and nutrients in ecosystems, and how fire influences native and nonnative species. Research results contribute to improved conservation, appropriate ecological use of fire, improved management strategies for ecosystem restoration and maintenance, and better, more defensible fuel management treatments.

Lodgepole fire history

A comprehensive tree-ring study has been initiated on the Tenderfoot Creek Experimental Forest to reconstruct historical fire regimes

Lodgepole pine-dominated forest is the third most extensive forest type in western North America, covering 15 million acres in the western United States. Over much of this extensive range, surprisingly little is known about historical fire regimes. While these regimes are commonly characterized as infrequent and stand-replacing, like those found in portions the Greater Yellowstone Area, evidence is mounting that lodgepole forests also sustained low- to mixed-severity fire regimes that resulted in complex forest age structures. In addition, we know little about the consequences of historical fire in lodgepole forests on vegetation composition, structure, and fuels or how they vary across landscapes in response to topography and microclimate. Understanding the causes and consequences of spatial variation in historical fire regimes is important for managing lodgepole forests across the west and for predicting how fire may shape forests in the future.

The Tenderfoot Creek Experimental Forest (TCEF) in central Montana is typical of high-elevation lodgepole pine forests east of the Continental Divide in the Northern Rocky Mountains and is occupied primarily by stands of lodgepole, sometimes mixed with Engelmann spruce and subalpine fir. A pilot-scale fire history study conducted at TCEF in the early 1990s suggested that that about half

Finn Leary assessing a fire-scarred lodgepole pine tree. Photo courtesy of Helen Smith
the forested land is multi-aged. It is well
documented that extensive high-severity
fires select for cone serotiny in pines, but
anecdotal observations suggest that only
half the lodgepole at TCEF have
serotinous cones and fire scars are
common so mixed-severity fires may have
been more common than previously
thought. Written records of fire at TCEF
include only the past century and post-
date a time of great change in land use
and hence fire regimes. Fortunately, tree
rings provide a multicentury record of fire
and we have successfully used them to
reconstruct historical mixed-severity fire
regimes in lodgepole forests elsewhere.

We will answer the following questions: (1)
How and why did historical fire regimes
vary across TCEF over the past several
centuries? (2) How did this variation drive
modern fuel and forest structure,
composition, and cone serotiny? We have
completed one field season thus far and
are currently processing the wood
samples and data.

**Focus Areas:** Fuel Dynamics, Fire Effects

**For more information,** contact: Helen
Smith at hsmith04@fs.fed.us

**Prairie-Forest Edge Fire History**

Tree-ring reconstruction of fire history at
the forested eastern edge of the
Palouse prairie, Idaho

Fires are widespread in prairies globally.
Fire often perpetuates grasslands by
counteracting tree encroachment, yet
there is often little record of this fire
preserved in the grasslands. Fortunately
adjacent woodlands can contain long-lived
tree species capable of recording fire
occurrence via cambial scars. These fire
scars can be dated dendrochronologically
to determine the past occurrence of fire
in the adjacent grasslands. The Palouse
prairie of eastern Washington and
adjacent Idaho was a mixed grass and
shrub biome with isolated trees before
95% of it was converted to agriculture.

Early ecologists argued that fire was not
important in maintaining the Palouse
prairie because relatively moist conditions
there were conducive to rapid

![Fire-scarred section removed from a live lodgepole pine tree. Photo courtesy of Helen Smith](image)

![Locations of our sampling sites at the edge of what was historically Palouse prairie, but is now cultivated land.](image)
decomposition of fuel and lightning is relatively uncommon. However, it has been suggested more recently that fires were historically frequent there because the rolling terrain is conducive to fire spread, humans were likely igniting fires in the past, and summers are long and dry. Strong evidence for or against the role of fire could be obtained from adjacent forests. The eastern edge of the Palouse prairie abuts mixed-conifer forest where fire scarred ponderosa pine trees are common. Understanding the past role of fire on the fringe of the Palouse prairie and in the western-most forests of the Rocky Mountains will provide guidance for how to manage these landscapes into the future.

Preliminary analysis has revealed forested sites at the edge of the Palouse burned frequently (every 6±4 years) between 1650 and 1900, suggesting that fire was important in maintaining the Palouse Prairie in the past.

Focus Areas: Fire Effects

For more information, contact: Emily Heyerdahl at eheyerdahl@fs.fed.us

---

**Fire-Induced Tree Mortality**

This project is a continuation and expansion of several past research projects on fire-induced tree mortality.

Tree mortality is an obvious and important consequence of fire in forested ecosystems. Yet our understanding of how fire kills trees is surprisingly rudimentary. Current models of fire-induced tree mortality use simple linear models optimized for a small set of commercially important species and most incorporate only single parameters for defense (bark thickness) and injury (crown scorch). Not surprisingly, the utility of these models have been called into question by managers and scientists. Crucially, we lack an understanding of the direct and indirect role of climate in determining post-fire tree mortality. This gap in understanding greatly limits our ability to accurately predict mortality from fire and extrapolate to novel climates, which in turn limits application of appropriate management actions to increase forest resilience to wildfire and estimate fire-caused feedbacks to the global carbon cycle.

We are conducting the first continental-scale characterization of climatic influences of fire-induced tree mortality using an unprecedented database of over 87,000 trees of 24 species across forests in the Western and Southeastern United States. Our analysis focuses on (1) evaluating the accuracy of currently used models and (2) assessing the influence of pre-fire climate on fire-induced tree mortality using the current framework of the existing software systems FOFEM, BehavePlus, and FFE-FVS.

Focus Areas: Fire Effects

For more information, contact: Sharon Hood at sharonmhoo@fs.fed.us
California tree mortality

Changes in fuel loading and conifer mortality risk factors due to bark beetles and drought in California

California is currently in the midst of a record-breaking drought and its forests are undergoing massive die-offs. This extensive tree mortality will drastically alter fuel loads, likely changing fire behavior and severity in fire-prone ecosystems and in the wildland-urban interface. Minimal information is currently available for post-bark beetle outbreak fuels data for use in fire behavior models, particularly for high levels of mortality in pinyon, ponderosa and Jeffrey pine and mixed conifer stands. Most work on bark beetle impacts to fuel loading has focused on mountain pine beetle in lodgepole pine, and there is extremely limited information for other forest types. High levels of tree mortality can rapidly alter fuel complexes, potentially resulting in increased fuel hazard which foster more intense and severe future fires. Dead pine trees in the red stage alter canopy fuel availability and may have higher ignition potential and burn more intensely. Surface fuel loading also may increase as foliage, branches, and trees decompose following successful bark beetle attacks.

In addition, recent work has yielded insights into predisposing factors to tree death; however, it is still unclear how site, stand, and individual tree factors interact to impact forest mortality. Such information is greatly needed to understand how past drought events affected tree growth and recovery and to identify possible thresholds of drought that lead to accelerated mortality.

Focus Areas: Fuel Dynamics, Fire and Fuel Management Strategies, Fire Effects

For more information, contact: Sharon Hood at sharonmhood@fs.fed.us

Wildfire effects in grand fir-hemlock forests

Grand fir and western hemlock mortality and regeneration dynamics after wildfire and salvage

The objectives of this study are to collect wildfire severity measurements, fire injury, and mortality in 2015 wildfires on the Idaho Panhandle National Forest in order to:

1) Evaluate accuracy of fire-induced tree
mortality model in FOFEM for grand fir and western hemlock

2) Develop mortality models for grand fir and western hemlock and compare with existing models

3) Compare regeneration dynamics in salvage and unsalvaged areas

The Grizzly and Tower wildfires burned on the Idaho Panhandle National Forest during the summer of 2015. These fires burned in areas of mesic forests dominated by mixed conifer consisting primarily of western hemlock, grand fir. The area historically was dominated by western white pine, but introduction of white pine blister rust and salvage logging in the mid-1900s greatly reduced white pine frequency. Genetically improved white pine is now available for planting to try to restore some of these sites to white pine forests.

This project will monitor fire-induced tree mortality in grand fir and western hemlock forests to validate and improve upon existing mortality models. It will also compare regeneration dynamics in salvage and non-salvage areas to determine the success of planted western white pine with different post-fire management.

Focus Areas: Fuel Dynamics, Fire and Fuel Management Strategies, Fire Effects

For more information, contact: Sharon Hood at sharonmhood@fs.fed.us.

Fire: A Vaccine for the Forest?

The impact of fire on conifer defenses

Disturbance and disturbance interactions drive multiple ecosystem processes over multiple spatial and temporal scales. This project investigated the role of frequent, low-severity fire in Pinus ponderosa (ponderosa pine) forests in altering the success of the irruptive insect Dendroctonus ponderosae (mountain pine beetle (MPB)). We first explored the factors controlling constitutive defenses without fire and then studied the impact of low severity on tree defenses.

Factors controlling constitutive defenses

Bark beetles (Coleoptera: Curculionidae, Scolytinae) cause widespread tree mortality in coniferous forests worldwide. Constitutive and induced host defenses are important factors in an individual tree’s ability to survive an attack and in bottom-up regulation of bark beetle population dynamics, yet quantifying defense levels is often difficult. For example, in Pinus spp. resin flow is important for resistance to bark beetles, but is extremely variable among individuals and within a season. While resin is produced and stored in resin ducts, the specific resin duct metrics that best correlate with resin flow remain unclear. The ability and timing of some pine species to produce induced resin is also not well understood. We investigated (1) the relationships between resin flow and axial resin duct characteristics, tree growth, and physiological variables and (2) if mechanical wounding induces ponderosa pine resin flow and resin ducts in the absence of bark beetles. Resin flow increased later in the growing season under moderate water stress and was highest in faster growing trees. The best predictors of resin flow were non-standardized measures of resin ducts, resin duct size and total resin duct area, both of which increased with tree growth. However, while faster growing trees tended to produce more resin, models of resin flow using only tree growth were not statistically significant. Further, the standardized measures of resin ducts,
density and duct area relative to xylem area, decreased with tree growth rate, indicating that slower growing trees invested more in resin duct defenses per unit area of radial growth, despite a tendency to produce less resin overall. We also found that mechanical wounding induced ponderosa pine defenses, but this response was slow. Resin flow increased after 28 days and resin duct production did not increase until the following year. These slow induced responses may allow unsuccessfully attacked or wounded trees to resist future bark beetle attacks. Forest management that encourages healthy, vigorously growing trees will also favor larger resin ducts, thereby conferring increased constitutive resistance to bark beetle attacks.

Impact of low severity on tree defenses
Induced defense is a common plant strategy in response to herbivory. Although abiotic damage such as physical wounding, pruning, and heating can induce plant defense, the effect of such damage by large-scale abiotic disturbances on induced defenses has not been explored, and could have important consequences for plant survival facing future biotic disturbances. Historically, low-severity wildfire was a widespread, frequent abiotic disturbance in many temperate coniferous forests. Native Dendroctonus and Ips bark beetles are also a common biotic disturbance agent in these forest types and can influence tree mortality patterns after wildfire. Therefore, species living in these disturbance-prone environments with strategies to survive both frequent fire and bark beetle attack should be favored. One such example is Pinus ponderosa forests of western North America. These forests are susceptible to bark beetle attack and frequent, low-severity fire was common prior to European settlement. However, since the late 1800s frequent, low-severity fires have greatly decreased in these forests.

We hypothesized that non-lethal, low-severity wildfire induces resin duct defense in P. ponderosa and that lack of low-severity fire relaxes resin duct defense in forests dependent on frequent, low-severity fire. We first compared axial resin duct traits between trees that either survived or died from bark beetle attacks. Next, we studied axial ducts using tree cores with crossdated chronologies in several natural P. ponderosa stands before and after an individual wildfire and also before and after an abrupt change in fire frequency in the 20th century. We show that trees killed by bark beetles invested less in resin ducts relative to trees that survived attack, suggesting that resin duct-related traits provide resistance against bark beetles. We then show low-severity fire induces resin duct production, and finally, that resin duct production declines when fire ceases. Our results demonstrate that low-severity fire can trigger a long-lasting induced defense that may increase tree survival from subsequent herbivory.

Focus Areas: Fuel Dynamics, Fire and Fuel Management Strategies, Fire Effects

For more information, contact: Sharon Hood at sharonmhood@fs.fed.us.

FIRESEV East

Expanding the Severe Fire Potential Map to the Eastern United States

In 2013, the FIRESEV project delivered several products, including a Severe Fire Potential Map (SFPM) for the conterminous western US, aimed at helping fire managers consider ecological effects of fire in their management decisions. The SFPM for the western US is a digital map that identifies the relative potential for any location to experience high burn severity, should a wildfire occur.
In the context of this study, burn severity refers to the degree to which aboveground vegetation and the soil surface are altered by fire, as mapped by satellite imagery products from the Monitoring Trends in Burn Severity (MTBS) project. FMI analysts developed the SFPM using empirical models that first related topography, vegetation, and fuel moisture variables to MTBS burn severity products, then used those relationships to spatially predict the likelihood for high severity fire. Beginning in 2014, the FIRESEV project was expanded to incorporate the eastern US. While this map serves as an extension to the western SFPM, it is important to note two key differences between these two products. First, due to the relative scarcity of high severity fire for much of the eastern US, FMI analysts broadened the term “severe” in the east to include an aggregate of both moderate and high severities, as opposed to the western map where “severe” is defined strictly as high severity. Second, FMI analysts found it necessary to use different continuous measures of burn severity from MTBS for the eastern US. In the west, the Relative differenced Normalized Burn Ratio (RdNBR) was used, but in the eastern FIRESEV analysis a combination of single-scene Normalized Burn Ratio (NBR), and multi-scene differenced Normalized Burn Ratio (dNBR) data were needed to get a large enough sample size for modeling. The end result of this project is a SFPM covering all of the conterminous US (CONUS). It is a raster geospatial product with 30m spatial resolution. A GTR describing detailed methods and results of a map accuracy assessment will be forthcoming in 2017.

**Focus Areas:** Fire and Fuel Management Strategies, Fire Effects

*For more information, contact:* Greg Dillon at gdillon@fs.fed.us
Whitebark Pine Climate Change (WBPCC)

Whitebark Pine Growth and Regeneration in a Changing Climate

While the most direct influences on whitebark pine (Abies lasiocarpa) health and mortality are white pine blister rust (Cronartium ribicola), mountain pine beetle outbreaks (Dendroctonus ponderosae) and decades of implemented fire exclusion policies, climate change impacts the intervals and severity of such beetle, rust, and fire disturbances, and may affect the growth and health of whitebark pine directly. With 51% of whitebark currently on the landscape dead, current modeling attempts for the future predict a decline in whitebark pines distribution upon the landscape and decreasing basal area in the remaining stands.

The objective of this study was to sample minimally disturbed sites throughout the northern Rocky Mountains within the United States and assess their mortality, regeneration, and ring-width growth as correlated with biophysical site characteristics and climate data product variables.

The research found that whitebark pine regeneration is decreasing proportionally on the landscape as subalpine fir undergrowth increases. Whitebark pine seedlings were captured in the sampling methodology on only 50% of the plots, while subalpine fir were present on 48%. Mature whitebark were still the dominant overstory in most of the sites sampled, but are being supplanted by late-seral subalpine fir in the mixed conifer stands and moist habitat types.

Descriptive mortality statistics on the stands showed that while whitebark pine has a higher mortality percentage on the stands than competing conifer species, when visually separated into decay classes, whitebark pine has significantly less recent mortality than the other species sampled (recent considered snag decay class 1).

Among the sites, maximum and minimum temperatures showed an increase of ~5-7 °F over the past 100 years, with precipitation decreasing since the 1980’s. There was a larger decline in average ring-width index (RWI) growth starting in 1998 than any of the 100 years prior, but in 2004 the ring-width growth demonstrated an increase till the end of the period sampled. When visually comparing the RWI mean against the plotted climate variables, RWI does appear to correlate with the warming minimum temperatures and dropping precipitation, although the increase of growth beginning in 2004 suggests an unmeasured factor, such as lengthening growing season, may be overriding any predicted growth decrease due to drought stress.

For geographical information on this project and how it fits with other Fire Lab Whitebark Pine research, visit the Whitebark Pine Story Map.

Focus Areas: Fire Effects
For more information, contact: Bob Keane at rkeane@fs.fed.us
Archiving tree-ring specimens and data for the future

This study will record the growth and regeneration of whitebark pine throughout the Rocky Mountains, with the advent of changing precipitation and temperature regimes as a result of climate change, whitebark pine (Pinus albicaulis) has seen a territory wide decline in population. While the most direct influences on whitebark pine health and mortality are mountain pine beetle (Dendroctonus ponderosae) outbreaks, fire exclusion policies, and the spread of white pine blister rust (Cronartium ribicola), climate change impacts the intervals and severity of such outbreaks, and may affect the growth and health of whitebark pine directly.

There is growing concern over the role climate change will have in the longevity of the species, as many believe that whitebark pine will continue doing poorly with the changing conditions and will be pushed to the tops of the mountains or further northward in latitude. Attempts at assisted migration further northward have begun, as the naturally slow growth rate of whitebark pine to an age capable of reproduction has inhibited the quicker territory expansion that some say is necessary for species survival without assistance. The use of SDM’s (species distribution models) have predicted suitable territory for whitebark pine expansion in northern British Columbia, as well, they have shown that whitebark pine does not presently inhabit all current predicted suitable habitat. Models have also predicted that with the addition of stand-replacing fires to the landscape, whitebark pine populations may be maintained. Given other advantages such as high genetic variability, moderate adaptability levels, and a resistance to blister rust, we may continue to see whitebark pine on our landscapes.

This study that will record the growth and regeneration of whitebark pine throughout the Rocky Mountains, along with the associated climatic and site variables that may affect such. 94 healthy sites were sampled in a variety of mountain ranges throughout Montana, Idaho, and Wyoming over the 2014 and 2015 field seasons, with multiple cores taken from each site. Using the data, current growth and regeneration trends will be assessed and compared to climate and site characteristics. Relationships observed may be used to predict continued presence given the changing climate and to help managers with restoration decisions and actions.

Focus Areas: Fire Effects
For more information, contact: Emily Heyerdahl at eheyerdahl@fs.fed.us
Fire and Fuel Management Strategies

To improve predictive ability for future fire regimes, FFS scientists and their research partners simulate landscape-level interactions among changing climate, fire regimes, and vegetation under different management scenarios. To better understand the drivers of historical fire regimes, they conduct fire history research. To improve the predictability of fire’s impacts on the biota, the atmosphere, and human health and safety, they use case studies, ecological research, and models based on physical fire processes and fuel dynamics research. FFS research improves fire and fuel management policies and practices, resulting in increased forest resilience, maintenance of forest cover, increased carbon capture and storage, and better understanding of the complex interactions between climate change and fire regimes. Moreover, improved fire danger rating and fire behavior prediction systems support sound fire and fuel management decision making.

Structures Lost to Wildfire 1999-2016

Maps of structures lost to wildfire for the period 1999-2016, based on FAMWEB ICS 209 database.

FMI analysts created two maps describing the number of structures lost to wildfire during the period 1999-2016 across the United States. One map shows each fire that occurred during the period of record, with symbols that increase as number of structures lost increases. The second map represents the total number of structures lost to wildfire throughout the period of record, by county. To create the maps, source data records were extracted from FAMWEB ICS 209 databases, then cleaned, organized, and presented spatially.

Focus Areas: Fire and Fuel Management Strategies,

For more information, contact: Eva Karau at ekarau@fs.fed.us.
Wind and Slope effects on Flame Scaling in Laboratory Fires

Wildfire spread strongly depends upon non-steady convective heat transfer by flame bursts that originate as buoyant instabilities in the flame zone. Previous studies with wind driven fires have shown these bursts have characteristic frequencies and forward travel distances which scale with flame size (0.1–2.5 m) and wind speed (0.1 – 2.2 m s⁻¹). New experiments were conducted on fires spreading upslope through laser-cut cardboard fuel beds at various angles on a tilting platform without wind. Data from slope-driven fires show flame intermittency and forward burst distances exhibit similar scaling using flame length and depth of the actively burning region. Static pressure measurements are also revealing of flame dynamics as well as a possible role in flame attachment on steep slopes.

Wildfire spread through vegetation follows a distinctive sequence of heat transfer and ignition processes that is quite different from urban or industrial fires. First, heating of most vegetation is highly dependent on convective heat transfer because the fine size and sparse distribution of vegetation foliage and grasses enhances cooling by ambient air. This is sufficient to offset heating by thermal radiation until the flame front is close enough for impingement. Second, flame impingement on fuel particles occurs intermittently as flame parcels burst forward from the burning zone. These bursts and non-steady flame patterns are still poorly understood but may have genesis as buoyant or hydrodynamic instabilities.

Top view of flame zone for fire spreading upslope. (A) dish-shaped parcels and location of thermocouple rake that recorded temperature fluctuations from forward flame bursts as the fire approached. Temperature time series (B) shows flame intermittency before ignition, (C) peak and trough structure as viewed toward the advancing flame front.

Sloping table 4x6 m with cement-board platform shown at 30 degrees. Photo by Mark Finney
Prior experiments with wind-driven fires have revealed that ignition of fine fuel particles was caused by intermittent heating with average frequencies of 2-8Hz. These frequencies exhibited Strouhal-Froude number scaling such that lower frequencies occurred with longer flames but higher frequencies with stronger winds. Radiant heat transfer to fuel particles also increased with the approach of the flame zone, but surface temperature measurements showed heating and cooling of a fuel particle was dominated by convective heat transfer rather than radiation. This study concerns results from additional experiments on flame characteristics in fires spreading up an inclined platform in the absence of wind.

Focus Areas: Fire and Fuel Management Strategies, Fuel Dynamics
For additional information, contact: Mark Finney at mfinney@fs.fed.us

Old tree responses

Long-term growth responses to stand density reduction treatments in mature pine forests of California

Ecological restoration of fire-adapted forest systems often focuses on density reduction with the retention of mature fire resistant pines to increase stand resiliency. However, there is disagreement about the ability of mature and old pines to respond to increased growing space, duration of the treatment effect and/or the treatment scale and intensity required to achieve a positive growth response. Variables such as drought, low live crown ratio, mechanical damage, and/or dwarf mistletoe infections can also limit the response in growth and vigor of mature pine to reductions in stand density. This project will determine to what degree thinning treatments affect 15 year growth rates of mature, 200+ year old ponderosa and Jeffrey pine. This is essential knowledge for developing treatment prescriptions, as old trees are scarce on the landscape and often a high priority for retention.

Focus Areas: Fire and Fuel Management Strategies,
For more information, contact: Sharon Hood at sharonmhood@fs.fed.us

Landscape risk – drivers, tradeoffs, and feedbacks

Modeling future fire and socioecological tradeoffs in coupled human-natural systems

Simulation models that incorporate the spatiotemporal interactions of vegetation succession, management, fire, and human dimensions can be used to analyze wildfire management policies as coupled human-natural systems. These platforms allow simulation of alternative policy scenarios and associated outcomes at the landscape scale providing the potential to not only inform decisions but also enhance collaborative planning.

We used Envision, an agent-based landscape model to quantify the impact of alternative land and fire management policies implemented over the course of
50 years in a 1.2 million ha multi-ownership landscape in central Oregon. The study area spanned the Deschutes National Forest, Confederated Tribes of Warm Springs, and lands managed by private industrial, private non-industrial landowners. We simulated scenarios that replicated business as usual forest management versus accelerated forest restoration and increased fire levels of wildfire. We analyzed long-term (50 year) projected landscape conditions as measured by wildfire activity, socioeconomic and ecosystem service metrics in the study area. One of the scenarios specifically examined long-term socioecological trade-offs of fire management policy that used restoration fires managed for ecological benefit.

Our findings indicated that alternative management strategies can have variable effects on landscape outcomes over 50 years for fire activity, socioeconomic, and ecosystem services metrics. Results showed that fuel management activities could reduce area burned by up to 40% over the 50-year simulation. Forest restoration treatments reduced fire severity over time, and fire exposure to structures in the wildland-urban interface. Management resulted in a net carbon loss, despite the higher occurrence of high-severity wildfire with increased management. In most scenarios increasing current levels of area treated was not sustainable through time because of a scarcity of stands eligible to treat according to current management constraints. This limits the ability to increase the scale and pace of forest restoration in this study area. Trade-offs between restoration goals (e.g., open forests with large fire-resistant trees) and habitat for species that require dense older forests were evident among management scenarios. Our results suggest that restoration wildfire can improve forest resilience and contribute to restoration efforts in fire-adapted forests, but there are trade-offs (wildlife habitat, smoke, area burned in fire-sensitive forest types). Increased levels of restoration fire is also constrained by the scarcity of natural ignitions occurring in the favorable locations and weather conditions. We found that doubling current rates of wildfire resulted in detectable negative feedbacks in area burned and fire intensity. The reduction in area burned was accompanied by substantially lower fire severity, and vegetation shifted to open forest and grass-shrub conditions at the expense of old growth habitat. Collectively, the trade-offs identified in these studies can contribute to the development of long-term management strategies on fire-prone landscapes, including the leveraging of fire-on – fire feedbacks as part of overall land management strategies. Applications of the model can also be used in collaborative settings to facilitate open

Contour plot of fire feedbacks from increased simulated wildfire over a 50 year landscape simulation. Contours show how the area burned in the current simulation year (% of study area) was affected by cumulative area burned in all previous years. Black lines show reference fire rotation intervals, or number of years to burn an area equal to the entire study area. The average area burned per year for all simulations was 2.2% or a fire rotation of about 45 years. Contours show a 10 year periodicity that correspond to the modeled vegetation regrowth after fires.
and transparent discussions and foster public support for forest management scenarios that generate negative impacts in the short term to achieve fire resilient landscapes in the future.

Focus Areas: Fire and Fuel Management Strategies, Fire Ecology, Smoke Emissions and Dispersion
For more information, contact: Alan Ager at aager@fs.fed.us

Bark beetle outbreaks in lodgepole pine

Lodgepole pine forest host characteristics influence mountain pine beetle outbreak severity in the Northern Rocky Mountains

Mountain pine beetle (Dendroctonus ponderosae Hopkins; MPB) is an aggressive bark beetle that attacks numerous Pinus spp. and causes extensive mortality in lodgepole pine (Pinus contorta Douglas ex Loudon; LPP) forests in the western United States and Canada. Past research suggests that when climate conditions are favorable, forest age is the most important factor influencing host susceptibility and outbreak severity. However, stand age is a difficult forest attribute to measure and not available over large spatial extents compared to other host tree characteristics such as tree size and density. We used available pre-outbreak LPP characteristics and mountain pine beetle attack severity data to test which host characteristics were most influential on attack severity during the 2000s MPB outbreak in the Northern Rockies region at the subwatershed scale.

Classification analysis of the simplest model indicated that the highest severity attack level was most likely to occur in subwatersheds where mean basal area was greater than 50 11.5 m2/ha and quadratic mean diameter was greater than or equal to 18 cm. Prior to the outbreak, 28% of subwatersheds contained LPP is this high susceptibility state (as defined by model results), and 51% of the susceptible subwatersheds were severely impacted by MPB-caused mortality in at least 10% of the LPP forests in that subwatershed. The results from this study indicate that during the 2000s Northern Rockies MPB outbreak the most important stand characteristics for describing attack severity in lodgepole pine were basal area and quadratic mean diameter. Other studies suggest that the extent of available host trees may have been facilitated by forest management history and fire exclusion. Research that tests the validity of this assumption could provide valuable information to guide management practices and mitigate LPP host characteristics that foster large-scale, severe MPB outbreaks.

Focus Areas: Fire and Fuel Management Strategies,
For more information, contact: Sharon Hood at sharonmhood@fs.fed.us.
Science Synthesis and Delivery

Scientific publications form the foundation of science delivery. Synthesis of past research builds on this foundation. FFS is committed to delivering new science knowledge in forms usable by scientists and resource managers alike. While FFS synthesis and delivery efforts are anchored in refereed scientific publications, science delivery includes the entire range of communications media to help land managers apply new and existing research, including computer programs, photo guides, and mentoring. Additional products include presentations, classes, field tours, and training materials. To develop and test products, FFS personnel collaborate with users and other stakeholders to design new ways to exchange information and bring science into application. FFS personnel provide educational programs for children and young adults. They also maintain the website http://www.firelab.org, where information about FFS publications and products is available. The Program's Fire Modeling Institute (FMI) is an essential component of this focus area.

Conservation Education

Engaging and educating students and the public about wildland fire science

Wildland fire draws the public’s attention every summer, but public understanding of fire is limited. The Missoula Sciences Fire Lab provides tours, workshops, presentations, and educational curricula and materials to help increase public understanding of the science of wildland fire. In FY17, the Fire Lab’s Conservation Education program reached more than 1,900 students and 650 adults (up 180% from FY16):

- Fire Lab staff provided 7 tours for over 300 1st-12th grade students and 38 teachers and other adults. Each tour included presentations and hands-on activities from the FireWorks Educational Program. Students used hands-on activities to investigate fire behavior, and used fire-scarred tree sections and feltboards to “tell the stories” of fire’s role in Rocky Mountain forests.
- We led activities in 5 classrooms, 5 field sites, and 1 elementary school “Science Night”, teaching students at the Elementary, Middle, and High School levels. These presentations reached about 900 students and 100 adults.
- We loaned FireWorks educational trunks to 8 teachers, who used them to teach approximately 235 students.
- We held our annual two-day workshop in Montana, which taught over 30 activities from the FireWorks curriculum to 10 educators.
- We also participated in the Missoula County Fair, and discussed wildland fire science with about 1,000 adults and children.

Focus Areas: Science Delivery, FMI

For more information, contact: Ilana Abrahamson at ilanalabrahamson@fs.fed.us
FireWorks Educational Program Expands

The FireWorks Educational Program Expands: New Activities, More Grade Levels, New Regions, More Accessible, and More Fun!

Wildland fire draws the public’s attention every summer, but public understanding of fire is limited. The FireWorks Educational Program aims to increase the public’s understanding of wildland fire, especially students in Kindergarten through 12 grade. FireWorks uses fun, hands-on activities to teach students about wildland fire science. It covers the physical science of wildland fire, fire effects on the environment, fire ecology, fire history, and people’s relationships with fire.

The Northern Rocky Mountains and Northern Cascades FireWorks program has been used extensively since 2000 and interest in the program is widespread. To meet increasing interest and incorporate the latest science, FireWorks is being expanded and revised to reflect recent advances in fire research and current national educational standards. The new program consists of separate curricula for elementary, middle, and high school levels and is comprised of about 20 activities at each level.

Newly published in 2017 is the FireWorks program covering ecosystems in the Sierra Nevada. Like all FireWorks programs, it also includes activities that cover physical fire science and fire effects on the environment. The FireWorks program for the Sierra Nevada was developed in collaboration with professionals from the Plumas Unified School District and Plumas National Forest. FireWorks has a new website hosted on FRAMES. Educators can download entire curricula or individual lessons, find locations of FireWorks trunks, and find out about future workshops.

Focus Areas: Science Delivery, FMI

For more information, contact: Ilana Abrahamson at ilanalabrahamson@fs.fed.us

Plumas Unified School District teachers examining fire scars to learn about fire history on the Plumas National Forest
Wildfire Hazard Assessment  
- Chelan County, WA

Wildfire hazard assessment supports community wildfire planning in Chelan County, WA.

FMI provided a spatial wildfire hazard assessment for a Community Planning Assistance for Wildfire (CPAW) analysis in Chelan County, WA. The assessment is based on RMRS wildfire risk assessment science, and includes wildfire hazard maps at local and landscape scales, along with ancillary maps of Wildland Urban Interface and Mitigation Difficulty.

Focus Areas: Fire and Fuel Management Strategies,

For more information, contact: Eva Karau at ekarau@fs.fed.us.
Applications and Products

In addition to scientific research projects and data products, FFS researchers are responsible for maintaining and updating a number of national computer applications. All of them are available on our website (http://www.firelab.org), and they cover the range of fire modeling from fire behavior to fire danger to fire ecology.

**BehavePlus Fire Modeling System**

The BehavePlus fire modeling system is a nationally supported desktop application that models fire behavior, fire effects, and aspects of the fire environment.

BehavePlus is used to model surface and crown fire spread rate and intensity, transition from surface to crown fire, fire size, effect of containment efforts, tree scorch height and mortality, fuel moisture, wind adjustment factor, spotting distance, and more. BehavePlus is not limited to a specific application, but rather is designed to be used for any fire management application for which fire model results are useful. It is used by federal, state, and local land management agencies, universities, consultants, and others, both nationally and internationally. Outputs from BehavePlus are used for a range of applications including wildfire prediction, prescribed fire planning, and fuel hazard assessment, as well as communication, education, and training. More information is available at our website: [http://www.frames.gov/behaveplus](http://www.frames.gov/behaveplus).

A Service Level Agreement between Washington Office Fire and Aviation Management (WO F&AM) and FMI ensures FFS staff are available to assist the National Fire Applications Help Desk in answering questions regarding BehavePlus use and operation. In 2016, FFS staff responded to multiple technical support requests, presented two workshops at the International Association of Wildfire Conference in Portland, Oregon, and developed materials for a series of workshops on using BehavePlus for prescribed fire to be presented in FY2017 in the southeastern U.S.

BehavePlus was recently updated to include more than 20 new and improved features, including changing how flanking fire is calculated in the surface module, as well as adding new analysis variables and special case fuel models. The beta version of BehavePlus v6 is available on the website. Lessons and documentation are also being updated to reflect changes in the application.

**Focus Areas:** Science Delivery, FMI

*For more information, contact:* Faith Ann Heinsch at faheinsch@fs.fed.us

**BehavePlus Online Training Course**

Introduction to BehavePlus Web-Based Training

The BehavePlus fire modeling system has been used in numerous courses sanctioned by the National Wildfire Coordinating Group (NWCG) since the 1990s. As time has passed, course instructors have noticed a widening disparity between the analytical skills needed by students and the skills that
students actually possess. This gap is probably most noticeable for prospective students that are ready to take S-490 Advanced Fire Behavior Calculations or Rx-341 Prescribed Fire Plan Preparation. Both courses requires a candidate student to demonstrate proficiency in BehavePlus, both to pass the exam to get into the course and in the course itself. Currently, no formal “how to” class exists to teach students how to use BehavePlus effectively. To fill this need, some regions have offered workshops or webinars to help prepare students prior to the classroom portion of a course.

To help students gain the necessary analytical skills and increase their analytical capacity in the field, we are developing a web-based training that will offer students a fundamental understanding of how to use the different modules in BehavePlus and how to select the appropriate inputs/outputs depending on the information needed. There are three courses in the Introduction to BehavePlus series. The core module covers the basics of using BehavePlus for fire behavior modeling for surface and crown fire. Using BehavePlus in Prescribed Fire Planning covers heading, flanking, and backing fire; mortality; and holding and contingency plans. Using the CROWN module provides a more in-depth look at modeling crown fire behavior. The intention of this web-based training is to build a foundation that will serve as the building blocks that students need to be successful both in these NWCG courses and beyond.

The BehavePlus web-based training will be hosted on the LCMS website maintained by NWCG.

Focus Areas: Science Delivery, FMI

For more information, contact: Faith Ann Heinsch at faheinsch@fs.fed.us or LaWen Hollingsworth lhollingsworth@fs.fed.us

Fire Behavior Pocket Guide

Revising Appendix B of the Fireline Handbook to be a Stand-alone Field and Classroom Fire Behavior Prediction Guide

The Fireline Handbook was originally created as a job aid and training reference by the National Wildfire Coordinating Group (NWCG). In 2013, the Fireline Handbook was officially replaced by the Wildland Fire Incident Management Field Guide as a desk guide for incident management and operational standards. The Incident Response Pocket Guide (IRPG) is now the field-going manual that firefighters carry with them. This left two appendices to the Fireline Handbook adrift. In 2015, the NWCG Fire Behavior Subcommittee identified updating Appendix B: Fire Behavior as a priority. The Appendix B is used in various fire behavior courses ranging from S-290 (Intermediate Wildland Fire Behavior) through S-490 (Advanced Wildland Fire Behavior Calculations).

Since the new guide will no longer be an appendix, it has been renamed the Fire Behavior Pocket Guide (FBPG). The first task was to identify the guide’s intended user group. The FBPG is meant for anyone with a basic level of fire behavior training, such as that provided by S-290. This guide, therefore, complements the Fire Behavior Field Reference Guide, a comprehensive guide for those with a moderate to advanced level of fire behavior training. The second task was to identify the information that needs to be included in the FBPG. For the most part, the calculations included in Appendix B
will be retained but the new guide will be reorganized to flow in a more logical order, be updated to include relevant new information (such as the 40 fuel models described by Scott and Burgan in 2005), include rules of thumb for quick calculations, and be a self-contained guide with all information necessary to obtain desired outputs. The maximum spotting distance nomogram has been replaced with a table, providing similar accuracy in an easier format. Justin Randall, Assistant Superintendent of the Flathead Interagency Hotshot Crew, has done the majority of the work to create a draft of the new guide. Justin is uniquely qualified to update the guide, as he has been a student of fire behavior since he was 9 years old when his grandfather started teaching him the fundamentals. While not a usual part of everyone’s childhood, Justin has continued this legacy by mentoring and training firefighters to enhance their fire behavior knowledge, while taking opportunities to advance his own knowledge as well.

Focus Areas: Fire and Fuel Management Strategies, Science Syntheses and Delivery, FMI

For more information, contact: LaWen Hollingsworth at lhollinsworth@fs.fed.us

FFI – Ecological Monitoring Application

FFI (FEAT/FIREMON Integrated) is an interagency plot-level monitoring software application designed to assist managers with collection, storage and analysis of ecological information.

FEAT-FIREMON Integrated (FFI) is an interagency, plot-level, ecological monitoring software application that is designed to assist managers in meeting mandated monitoring requirements. It is used in the U.S. Forest Service (USFS), National Park Service, Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (FWS), U. S. Geological Survey, and Bureau of Indian Affairs (BIA), and by tribes, state and local governments, nongovernmental organizations, and universities.

Each year the FFI management team prioritizes application updates to meet CIO requirements, ensure compatibility with underlying systems (Windows OS and ESRI products), fix bugs and add new functionality requested by users. The team also provides technical support (email, phone and Google Group) and, online and classroom training classes. FFI version 1.05.04 was released in August 2017.

Significant updates include improved 508 compliance of the FFI user interface, import (append or replace) of macro plot data and two new protocols with associated reports: photoloads and Logs – fixed-area. In FY2017, 62 students from FS, NPS, BLM, BIA, tribes, and non-federal groups attended a FFI training class and over 50 technical support requests were answered.

In the May 2017 FFI users’ survey 85% of respondents said they were satisfied or highly satisfied with the FFI software, 88% they were satisfied or highly satisfied with FFI technical support, 83% responded they were satisfied or highly satisfied with opportunities for training, 92% said FFI helps them support the mission of their organization and 78% said they used FFI data to support management decisions in the previous year.

Focus Areas: Fuel Dynamics, Smoke Emissions and Dispersion, FMI
FireFamilyPlus (FFP)

FireFamilyPlus is a desktop application that supports the spectrum of analysis tools required by fire managers to successfully use the National Fire Danger Rating System (NFDRS) and the Canadian Forest Fire Danger Rating System from weather climatology data.

FireFamilyPlus (FFP) is an agency-independent desktop application. It supports the spectrum of analysis tools required by fire managers to successfully use the National Fire Danger Rating System (NFDRS) and the Canadian Forest Fire Danger Rating System from weather climatology data. It can be used to calculate fire danger rating indices and components and summarize both fire and weather data. The program can display data, compute values, and statistically analyze data in graph or report form. FFP can summarize weather climatology to produce climatological breakpoints for fire management decision making. It generates the Fire Danger Rating Pocket Cards required by the 30-Mile Abatement Plan and supports Predictive Services’ functions at all the Geographic Coordination Centers.

FireFamilyPlus is the computational and analysis cornerstone for the biennial Advanced Fire Danger Rating course at the National Advanced Fire and Resource Institute (NAFRI) and annual Intermediate Fire Danger Rating (S-491) courses help by the various Geographic Area Training Centers throughout the country. It also provides climate summaries for techniques taught in the Long Term Fire Risk Assessment course (S-495) at NAFRI.

FY16 highlights include release of Version 4.2 in the fall of 2016 and transition to Version 5 that will encompass the major revisions and simplifications to the National Fire Danger Rating System (NFDRS2016). In 2016, FMI staff responded to more than 56 elevated tickets on FireFamilyPlus technical issues.

Focus Areas: FMI, Physical Fire Processes, Fire and Fuel Management Strategies, Science Synthesis and Delivery

First Order Fire Effects Model (FOFEM)

FOFEM is a computer program developed to meet needs of resource managers, planners, and analysts for predicting and planning fire effects.

FOFEM simulates four basic effects: 1) consumption of surface and ground fuels and the resultant fire intensity over time using the BurnUp model, 2) emissions and emission rate of PM10, PM2.5, CO, CO2, CH4, NOX and SO2 for flaming, smoldering and total combustion, 3) soil heating across a range of soil depths over time since ignition, and 4) tree mortality from surface fire.

In addition to the desktop application FOFEM is also incorporated in landscape models such as the Emissions Estimation System model used by the California Air Resources Board to model emissions from
wildland fire and prescribed burns. FOFEM version 6.4 was released in July 2017. The new version includes an option for using recently published and expanded emission factors, and three additions in the batch version: expanded emissions factors, post-fire tree mortality equations and option for selecting consumption equations for duff, litter, herb and shrub fuels. The technical lead responded about 15 technical support requests in FY2017.

Focus Areas: Fuel Dynamics, Smoke Emissions and Dispersion, FMI

For more information, contact: Duncan Lutes at dlutes@fs.fed.us

FuelCalc

FuelCalc is designed to help managers assess changes in ground, surface, and canopy fuel loading as simulated thinning, pruning, piling and prescribed fire treatments are applied.

FuelCalc is designed to help managers assess changes in ground, surface, and canopy fuel loading as simulated thinning, pruning, piling and prescribed fire treatments are applied. Initial fuel loading can be entered manually or using files exported from FFI. Outputs include canopy fuels (canopy bulk density, crown base height), load of surface and ground fuels, emissions, and fire behavior fuel model.

FuelCalc 1.5 was released in August 2017. This version includes updates made in FOFEM 6.4 (used for determining fuel consumption and tree mortality) and is now compatible with the latest FFI export files. The FuelCalc user guide was updated to reflect the changes in the application.

The technical lead responded about 5 technical support requests in FY2017.

Focus Areas: Fuel Dynamics, Smoke Emissions and Dispersion, FMI

For more information, contact: Duncan Lutes at dlutes@fs.fed.us

Severe Fire Weather Potential Mapping

Improvements to the Wildland Fire Assessment System: a new severe fire weather potential mapping system

Developers of the Wildland Fire Assessment System (WFAS) (https://www.wfas.net) have created a new automated fire potential forecast tool that integrates fire weather forecasts from the National Weather Service’s National Digital Forecast Database and combines those forecasts with initial conditions from 2000 remote automated weather stations to produce daily forecasts of the Energy Release Component, Burning Index and a combined product called the Severe Fire Weather Potential index.

The Severe Fire Weather Potential (SFWP) is a metric of fire behavior potential. It is an integral metric of both the Energy Release Component (ERC) and the Burning Index (BI) from the US National Fire Danger Rating System. Both ERC and BI are first forecast daily and then normalized to percentiles by comparing current values with historical values from a long-term, gridded historical fire danger climatology (Figure 1). The final SFWP raster is created by multiplying the categorical ERC percentile raster, hereafter referred to as the Spatial Preparedness Level (SPL) raster, times the
categorical BI percentile raster, hereafter referred to as the Spatial Fire Behavior Potential (FBP) raster (Figure 1).

This system is the first of its kind to provide operationally relevant fire behavior potential forecasts that can be used to improve firefighter situational awareness, reduce exposure and improve fire operations success.

Focus Areas: Fire and Fuel Management Strategies, Science Delivery, FMI

For more information, contact: Matt Jolly at mjolly@fs.fed.us

WIMS Development and Support

The Weather Information Management System (WIMS)

The Weather Information Management System (WIMS) is a mission critical, national system, managed and maintained by USDA, Forest Service's Fire and Aviation Management branch for interagency use. WIMS serves as the processor for the National Fire Danger Rating System (NFDRS), using weather observations and NWS forecast to generate indices, including Burning Index, Energy Release Component, Staffing Level and the Adjective Rating. FMI staff provide technical liaison to F&AM program managers to adapt new science into the NFDRS model in WIMS.

In 2016 FMI staff continued leading the science and technical implementation of NFDRS 2016 in the WIMS development environment, including: * Developed NFDRS 2016 calculator code block * Wrote detailed technical requirements documents for contract modifications * Designed and assisted in unit testing to insure calculators in FireFamilyPlus and WIMS produce the same outputs * Designed a new Comparison function in WIMS to review and compare index performance * Designed WIMS Model Management functionality FMI staff also provided national technical support for WIMS through the National Fire Applications Help Desk. In 2015 they assisted in resolving 38 elevated tickets on WIMS technical issues.

Focus Areas: Smoke Emissions and Dispersion, Science Syntheses and Delivery, FMI

For more information, contact: W. Matt Jolly at mjolly@fs.fed.us

WindNinja: Predicting winds for fire management

WindNinja a tool for simulating winds at fine spatial resolution in support of wildland fire management.

The interaction between wind and fire has been a point of keen interest in wildland fire research for nearly a century. Traditionally, fire managers have used intuition and personal experience to extend direct observations and coarse-scale forecast data (3 to 12 km) to estimate winds at discrete points of interest on a fire (e.g. a specific drainage or ridge). Due to the strong correlation between wind and fire spread, the uncertainty associated with this method is a primary contributor to inaccuracies in fire behavior model predictions. A multidisciplinary team has developed a model for simulating surface winds at spatial scales of 10s to 100s of m. The approach is non-traditional from a meteorological point-of-view; however, it has been shown to significantly increase
Because this research has such a potentially broad impact on fire management operations, communication with the fire management community through the entire research cycle has been a critical element. The wind model is currently used throughout the world to support wildland fire management and many other wind-driven activities. WindNinja has been downloaded and referenced in wildland fire-related studies around the world. One group of researchers used the model to study how winds contribute to canyon incision on Earth and Mars. Another group used it to model the dispersion of pheromones for training search and rescue dogs. As a rough measure of the interest in and use of this model, over the past 18 months more than 3000 individual IP addresses originating from 52 countries, spanning six continents, have initiated over 7 million WindNinja simulations. A mobile version of WindNinja was released in August 2016 for use on iOS and Android devices and has been installed on over 1600 unique devices. Ongoing work is focused on evaluating and enhancing the accuracy of the model and improving the user interface to make it as user-friendly as possible.

*Focus Areas: Physical Fire Processes, Smoke Emissions and Dispersion*

*For more information, contact:* Bret Butler at bwbutler@fs.fed.us, or Natalie Wagenbrenner at nwagenbrenner@fs.fed.us
The Research Continues: The White Cap Story

White Cap Wilderness Fire Research and Reunion

In 1964, Congress passed the Wilderness Act that called for select federal lands to be managed in such a way to leave them “unimpaired for future use and enjoyment as wilderness,” and for the “preservation of their wilderness character.” It also required that wilderness be “affected primarily by the forces of nature, with the imprint of man’s work substantially unnoticeable.”

The Wilderness Act gave agencies leeway when it came to the control of wildland fire in wilderness areas, and most agencies kept the Forest Service’s fire suppression policy. But a handful of foresighted administrators and researchers in the Forest Service began to question whether full suppression of fires met the spirit of the Wilderness Act, particularly when it called for “an area where the earth and its community of life are untrammeled by man.” Some, such as Bud Moore, the Northern Region’s director of fire control, saw fire suppression as altering forests that had evolved with fire. Others, such as Bill Worf, the region’s chief of recreation and lands, argued that “Letting lightning fires burn [in wilderness areas] is the ‘natural process.’

In 1970, Bud Moore, Bill Worf, and Orville Daniels, supervisor of the Bitterroot National Forest, initiated and championed a revolutionary project to allow fire to be reintroduced in the wilderness landscape. And in August of that year, fire researcher Bob Mutch of the Northern Forest Fire Laboratory (now the Missoula Fire Sciences Lab or “Fire Lab”) and regional forester Dave Aldrich were given three years to gather data, and develop and test a plan to manage, not just suppress, fires in the test area. Working in a 100-square-mile study area along the White Cap drainage of the Selway-Bitterroot Wilderness, Mutch, Aldrich, and their field crew collected fuel data under the direction of Fire Lab fuel specialist Jim Brown. By the end of the project in 1973, more than 1,000 plots had been measured and analyzed.

In the winter of 1971-72, with the three-year project nearing an end, the team divided the land into fire management zones – what they referred to as ecological units – and wrote a comprehensive fire management plan. Recommendations were made for each of the units, depending in part on conditions on the ground and if people or property were at risk. In July 1972, Moore, Daniels, and regional forester, Steve Yurich, all approved the management plan, so Bob Mutch and Orville Daniels flew to Washington, D.C. to present it to Chief Forester John McGuire. On August 17, 1972, Chief McGuire, a former researcher himself, approved the plan, and the very next day lightning ignited the Bad Luck Creek Fire in the Whitecap drainage. With the Chief’s approval behind them, the small, four-day fire was allowed to burn without any attempt to suppress it. For those in the Forest Service who viewed fire as a natural part of the landscape and had advocated for its return to some
fores

ted lands, August 18, 1972 was an important milestone in restoring the ecological integrity of wilderness areas, a day worthy of recognition.

Forty-five years later, on August 16-17, 2017, the Missoula Fire Sciences Lab hosted a reunion of many of those involved in the original White Cap project. Held in the Paradise Campground in the Bitterroot National Forest on the edge of the Selway-Bitterroot Wilderness, more than 25 researchers, regional foresters, and original alumni of the White Cap study met to remember the events of the early 1970s, and reflect on advances in wilderness fire management. The highlight of the reunion was a barbecue and panel discussion featuring some of the original White Cap participants, Orville Daniels, Bob Mutch, Jim Brown, and three of the original field crew who worked with Mutch, Aldrich, and Brown: Tim Beebe, Ron Milam, and Rick Oberheu.

The Fire Lab’s Bob Keane, Carol Miller with the Aldo Leopold Wilderness Research Institute, Paul Hessburg, Sr. with the Pacific Northwest Research Station, and their field crew also attended, marking the first days of a new study to re-measure the fuels in the White Cap. With more than a thousand plots in the original study area, measured as often as three times from 1970 to 1974, this new generation of fire researchers and their crew are re-measuring the same area to evaluate vegetation and fuel changes over more than 40 years of successful fire policy implementation. The researchers will use the original White Cap field data to create detailed fuels and vegetation GIS layers to represent fuel conditions in 1974, and augment these layers with annual fire severity maps from 1974 to 2014. Data-gathering techniques will be used to ensure that the same area can be re-measured in the future.

For more information, contact Bob Keane: rkeane@fs.fed.us
The Fire, Fuel, and Smoke Science Program focuses on basic and applied research related to wildland fire, including wildland fire processes, terrestrial and atmospheric effects of fire, and ecological adaptations to fire. Results from this research are disseminated in a number of ways, including publications. The following list, separated by the focus areas, provides an overview of articles published in 2017. Links are provided for publications where possible.

**Physical Fire Processes**

https://www.treesearch.fs.fed.us/pubs/50530

https://www.fs.usda.gov/treesearch/pubs/54956

https://www.fs.usda.gov/treesearch/pubs/54953

https://www.treesearch.fs.ed.us/pubs/54505

de la Mata, Raul; Hood, Sharon; Sala, Anna. 2017. Insect outbreak shifts the direction of selection from fast to slow growth rates in the long-lived conifer Pinus ponderosa. PNAS. doi: 10.1073/pnas.1700032114.  
https://www.treesearch.fs.fed.us/pubs/54506

**Fuel Dynamics**

https://www.treesearch.fs.fed.us/pubs/53496


Hansen, Andrew; Ireland, Kathryn; Legg, Kristin; Keane, Robert; Barge, Edward; Jenkins, Martha; Pillet, Michiel. 2016. Complex challenges of maintaining white bark pine in Greater Yellowstone under climate change: A call for innovative research, management, and policy approaches. Forests. 7(3): 54. https://www.treesearch.fs.fed.us/pubs/50803


Smoke Emissions and Dispersion


Fire Ecology


Fischer, A Paige; Spies, Thomas A; Steelman, Toddi A; Moseley, Cassandra; Johnson, Bart R; Bailey, John D; Ager, Alan A; Bourgeron, Patrick; Charnley, Susan; Collins, Brandon M; Kline, Jeffrey D; Leahy, Jessica E; Littell, Jeremy S; Millington, James DA; Nielsen-Pincus, Max; Olsen, Christine S; Paveglio, Travis B; Roos, Christopher I; Steen-Adams, Michelle M; Stevens, Forrest R; Vukomanovic, Jelena; White, Eric M; Bowman, David MJS. 2016. Wildfire risk as a socioecological pathology. Frontiers in Ecology and the Environment. 14(5): 276-284. https://www.fs.usda.gov/treesearch/pubs/52512


Fire and Fuel Management Strategies


Pimont, Francois; Parsons, Russell; Rigolot, Eric; Coligny, Francois de; Dupuy, Jean-Luc; Dreyfus, Philippe; Linn, Rodman R. 2016. Modeling fuels and fire effects in 3D: Model description and applications. Environmental Modelling and Software. 80: 225-244. https://www.treesearch.fs.fed.us/pubs/53495


Fischer, A. Paige; Spies, Thomas A; Steelman, Toddi A; Moseley, Cassandra; Johnson, Bart R; Bailey, John D; Ager, Alan A; Bourgeron, Patrick; Charnley, Susan; Collins, Brandon M; Kline, Jeffrey D; Leahy, Jessica E; Litell, Jeremy S; Millington, James DA; Nielsen-Pincus, Max; Olsen, Christine S; Paveglio, Travis B; Roos, Christopher I; Steen-Adams, Michelle M; Stevens, Forrest R; Vukomanovic, Jelena; White, Eric M; Bowman, David M. J. S. 2016. Pathology of wildfire risk: A characterization of social and ecological dimensions. Research Brief 11. Northwest Fire Science Consortium. 2 p. https://www.fs.usda.gov/treesearch/pubs/54926

Hulse, David; Branscomb, Allan; Enright, Chris; Johnson, Bart; Evers, Cody; Bolte, John; Ager, Alan. 2016. Anticipating surprise: Using agent-based alternative futures simulation modeling to identify and map surprising fires in the Willamette Valley, Oregon USA. Landscape and Urban Planning. 56: 26-43. https://www.fs.usda.gov/treesearch/pubs/54960


Science Synthesis and Delivery

https://www.treerearch.fs.fed.us/pubs/54271

https://www.fs.usda.gov/treerearch/pubs/54903