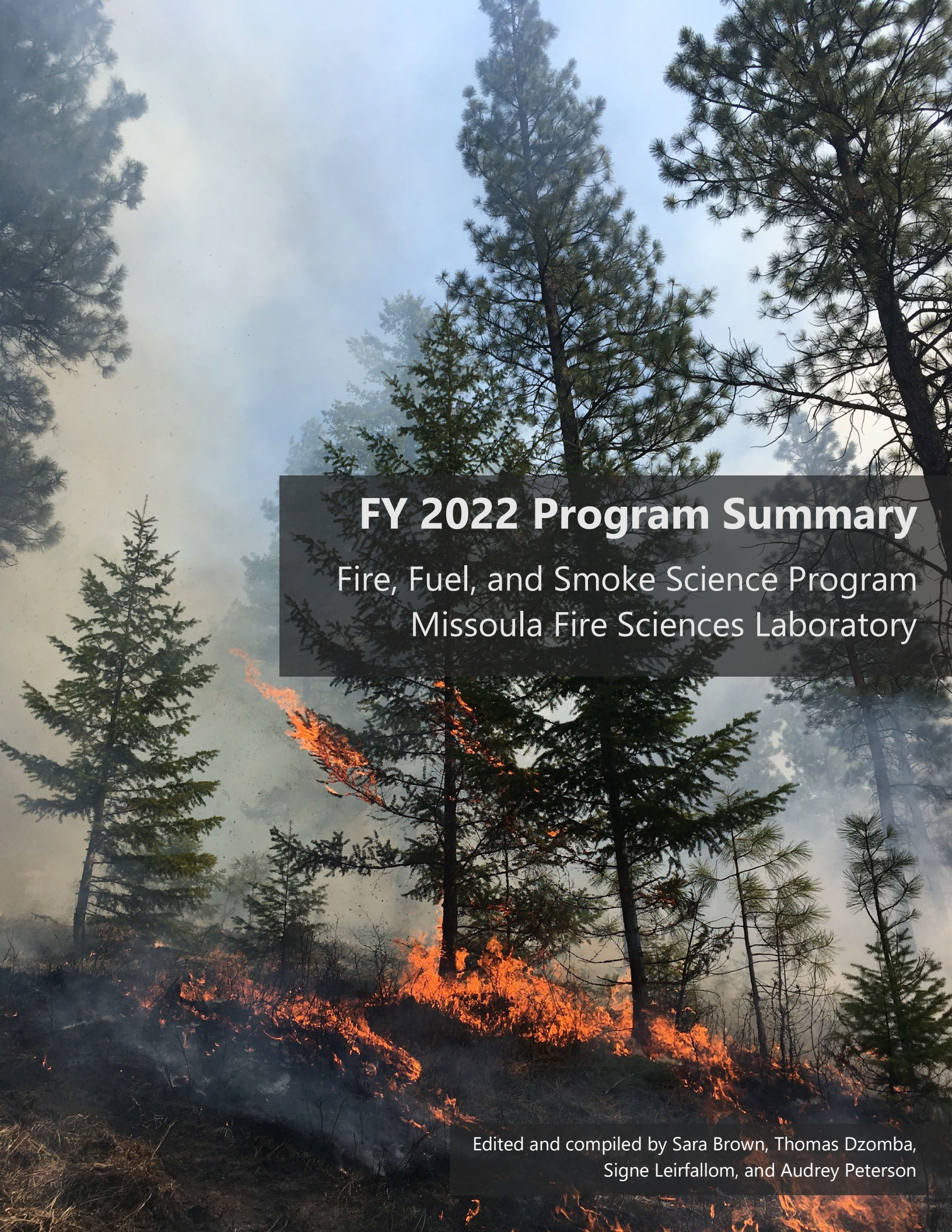

FY 2022 Program Summary

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

Edited and compiled by Sara Brown, Thomas Dzomba,
Signe Leirfallom, and Audrey Peterson

FIRE, FUEL, AND SMOKE
SCIENCE PROGRAM
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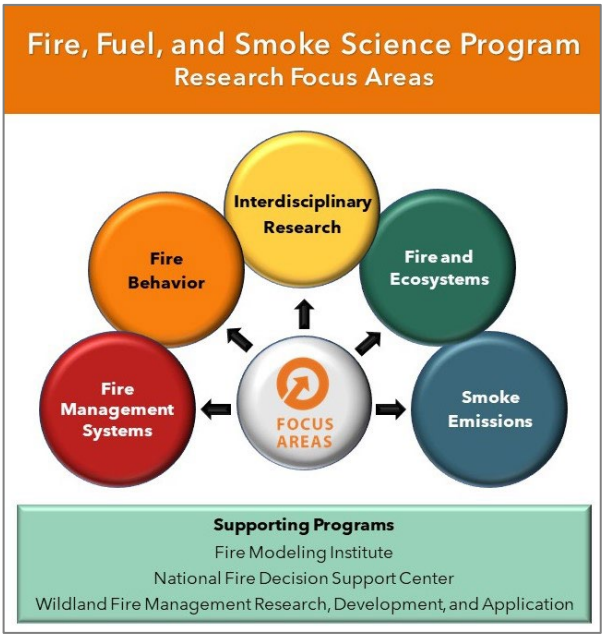
Contents

Fire Fuel and Smoke (FFS) Science Program

The Missoula Fire Sciences Laboratory (Fire Lab) was established in 1960 "to find scientific solutions for better managing the nation's wildland resources and to research ways to improve forest fire prevention and suppression." The Fire Lab is part of the Rocky Mountain Research Station's (RMRS) Fire, Fuels, and Smoke (FFS) Science Program, which employs nearly 90 scientists, professionals, and technical and administrative support staff.

Although the facilities at the Fire Lab include a world renown assemblage including an experimental combustion chamber, wind tunnels, chemistry and fuel processing labs, and a place-based experimental forest, the most impressive and inspirational part of the program is our people. The diversity of expertise and experience represented by our Program's workforce is critical to exploring the complexities of fire science and management.

In this FY 2022 Program Summary, we proudly present our accomplishments under our newly signed program charter: **Five Research Focus Areas—Fire Behavior, Fire and Ecosystems, Smoke Emissions, Fire Management Systems, and Interdisciplinary Science.** We also highlight the impactful work of the Fire Modeling Institute (FMI), Wildland Fire Management Research Development and Applications (WFM), National Fire Decision Support Center (NFDSC), and Innovation and Organizational Learning Research Development and Applications (IOL). Our work would not be possible without strong collaborations with a diverse set of partners, also described in this report.



Highlights from our work in FY 2022 include:

- **Wildfire Risk to Communities (WRC)**
  FMI worked with the FS Office of Tribal Relations, Fire and Aviation Management, the Bureau of Indian Affairs, and the DOI Office of Wildland Fire to update *Wildfire Risk to Communities* to include information about wildfire risk to homes, wildfire exposure, wildfire likelihood, and vulnerable populations for tribal areas in all 50 states.

- **Secretarial Memo Response**
  The Fire Modeling Institute (FMI) and scientist Karin Riley collaborated with the Washington Office, helping to prepare a response to the June Secretary's Memo on Climate and Carbon Resilience (section 2.a.(1)). The memo called on the agency to update the fireshed risk map by the end of November 2022 to include risks to ecosystem

values and risks to under-served and socially disadvantaged communities. It also requires that carbon storage data be added to the fireshed risk map.

- **Guidelines for Greenhouse Gas Quantification in Agriculture and Forestry Updated**
  Shawn Urbanski and Karin Riley took a lead role in the USDA effort to update the *2014 Entity Guidelines for Greenhouse Gas Quantification in Agriculture and Forestry*. Shawn and Karin were the conceptual architects and lead authors of the fire subchapter, which focused on immediate fire effects on greenhouse gas emissions and carbon pools.

- **Textbook: Wildland Fire Behaviour: Dynamics, Principles, and Processes**
  FFS scientists Mark Finney, Sara McAllister, Torben Grumstrup, and Jason Forthofer published *Wildland Fire Behaviour: Dynamics, Principles, and Processes* (https://ebooks.publish.csiro.au/content/wildland-fire-behaviour).

- **Wildland Fire Smoke in the United States: A Scientific Assessment**
  Forest Service Research (including Shawn Urbanski) published *Wildland Fire Smoke in the United States: A Scientific Assessment* (https://link.springer.com/book/10.1007/978-3-030-87045-4). This publication summarizes the current understanding of smoke science and issues around smoke from wildland fires and provides information for improving smoke and fire management.

- **Mortality of Fire-Resistant Giant Sequoias**
  FFS scientist Sharon Hood participated in a study that looked at increases in mortality of giant sequoias (*Sequoiadendron giganteum*) due to recent wildfires: https://www.fs.usda.gov/research/rmrs/news/highlights/giant-sequoia-forests-losing-resilience-wildfires

- **Large Wildfire Driven Increases in Nighttime Fire Activity Observed**
  FFS scientists, Patrick Freeborn and Matt Jolly, published a paper on large wildfire driven increases in nighttime fire activity across CONUS. This work highlights important safety-related challenges in fire behavior. https://www.fs.usda.gov/research/treesearch/63575

- **Interagency Fuel Treatment Decision Support System (IFTDSS)**
  WFM continued to enhance the Interagency Fuel Treatment Decision Support System (IFTDSS) a collaborative effort between the US Forest Service and the Department of the Interior. IFTDSS is a web-based application designed to make fuel treatment planning and quantitate wildfire risk assessments more efficient and effective.

I am proud and honored to share the many accomplishments contained in this report. The FFS program continues to make a positive impact to fire science and management across the U.S. and internationally.

Sara Brown, Program Manager
Fire, Fuel, and Smoke Science Program
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FFS In the Media

FFS Program science is frequently featured in the media, with coverage ranging from local to international. In FY 2022, the FFS Program received over 50 media requests covering a wide range of fire science topics. This attention helped our mission to deliver science to both managers and the general public.

2022 Media Highlights Included:

- **MEGAFEUX, LE NOUVEL ÂGE DU FEU:** MEGAFEUX, LE NOUVEL ÂGE DU FEU, or "The Big Burn", is a documentary film released in March 2022 for France TV. The film discusses humanity's relationship with fire and whether that relationship needs to change given the growth of megafires and other factors like climate change. The film features Senior Scientist Mark Finney, Research Mechanical Engineer Sara McAllister, and Research Mechanical Engineer Torben Grumstrup.

- **Atlas Obscura:** Tribal Liaison Serra Hoagland was featured in Atlas Obscura's *Women in Conservation* series, highlighting "women of science who are protecting our planet's biodiversity in innovative ways." The article discusses how Serra incorporates both Indigenous traditions and modern methods into her work. https://www.atlasobscura.com/articles/indigenous-forest-management-hoagland

- **Freethink:** Senior Scientist Mark Finney, Research Mechanical Engineer Sara McAllister, Mechanical Engineer Jason Forthofer, and Physical Scientist Faith Ann Heinsch were filmed at the Fire Lab for a story about developing a new model to one day replace the Rothermel Spread Model. https://www.youtube.com/watch?v=iIp6fpu0azY

- **Fire Modeling Institute Director Greg Dillon** gave several interviews talking about Wildfire Risk GIS data and modeling, and Wildfire Risk to Communities. Media outlets included National Public Radio, The New York Times, and Reuters.

- **Wired:** The Fire Lab hosted a film crew from WIRED who did a documentary on the Fire Lab as part of their Field Trip series. The film featured Senior Scientist Mark Finney, Research Ecologist Sharon Hood, Soil Scientist Jim Reardon, Chemist Steve Baker, and Tribal Liaison Serra Hoagland, and highlighted research on fire behavior, tree physiology, soil heating, wildfire smoke, and fire suppression and wildlife. https://www.youtube.com/watch?v=-WvJwlgq8vI

For more information, contact Thomas Dzomba at: thomas.dzomba@usda.gov

Partnerships

Partnerships and cross-disciplinary research teams are critical to addressing the growing number of increasingly complex questions related to wildland fire. FFS researchers and professionals 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, non-governmental organizations, and international partners.

In June 2022 the FFS program hosted the Forest Service National Partnership Office (NPO) for a tour of the Missoula Fire Sciences Laboratory and roundtable discussion. The meeting provided an opportunity to highlight partnership opportunities within the FFS program, along with lessons learned and insights on how these partnerships are working on the ground. The program gained valuable feedback from the NPO on partnership efforts, including improved focus on diversity, equity, inclusion, and acceptance.

Dr. Sara Brown leading the roundtable discussion with the National Partnership Office. Photo credit: Pam Sikkink

Partnerships utilize the strengths of each member to produce more effective and far-reaching research and to develop and deliver new tools and scientific understanding. In FY 2022 the FFS program continued to benefit from long-term agreements with partners such as Headwaters Economics, Los Alamos National Laboratory, Pyrologics, Technosylva, The University of Idaho, The University of Montana, Salish Kootenai College, and many others. The program also hosted several participants from the Fulbright Scholars program and the Oak Ridge Institute for Science and Education (ORISE), providing young scholars practical experience in a research environment while furthering development of program science through their knowledge.

Internationally, FFS researchers and science professionals have developed partnerships with colleagues from nearly every continent. As the world reopened from the COVID-19 pandemic, program scientists were once again able to engage face to face with international partners in 2022. FFS researchers and science professionals participated in international conferences in Canada and Italy, and assisted partners with fire management planning, modeling, and risk mapping in the Czech Republic, the Republic of Georgia (in partnership with Forest Service International Programs), Portugal, and several countries in South America. In addition, the program hosted scholars from Australia and Germany, working on fire danger and risk mapping products.

With our partners, we continue to develop, synthesize, and deliver scientific products, applications, and geospatial technology to improve fire and fuels management.

For more information, contact Sara Brown at: sara.h.brown@usda.gov

Collaborative Programs

FFS administers several collaborative programs that promote fire research and science delivery

Fire Modeling Institute (FMI)

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.

FMI is a joint effort between the FFS Program and Washington Office Fire and Aviation Management (FAM). It is a center of expertise that connects and supports scientists, land managers, wildfire practitioners, and the public in the use and application of wildfire science, data, and analysis. FMI operates in four primary areas:

- **Analysis and Support.** FMI helps to transfer knowledge and analytical methods from research to the field through applied projects involving fire behavior analysis and modeling, fire effects modeling and spatial data analysis.
- **Application.** FMI scientists and analysts are recognized subject matter experts for a range of wildland fire software systems and applications used by fire managers and practitioners. FMI ensures that the applications we manage are regularly updated to contain the best available science.
- **Science Synthesis and Delivery**. FMI provides synthesis and delivery of fire science information for field practitioners through the Fire Effects Information System (FEIS).
- **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 public.

For more information, visit: https://firelab.org/collaborative-programs/fmi

Fire Effects Information System (FEIS)

As part of FMI, the FEIS team of ecologists reviews thousands of published scientific articles and reports about wildland fire and uses the information to write syntheses that are published online in the Fire Effects Information System (FEIS). This enables managers to easily find science relevant to land management decisions. FEIS offers four peer-reviewed publication types:

- **Species Reviews.** This year, FEIS ecologists focused on some species of high-concern, as requested by land managers. These included the iconic saguaro, three southwestern riparian trees—Arizona walnut, Arizona sycamore, and desert-willow—and two nonnative invasive grasses—buffelgrass and ventenata.
- **Fire Regime Syntheses** integrate LANDFIRE data with information from the scientific literature to provide in-depth information on historical fire regimes and to address contemporary changes in fuels and fire regimes.

- **Fire Regime Reports** summarize and facilitate access to LANDFIRE data and, along with Fire Regime Syntheses, connect this LANDFIRE data to all 1,089 Species Reviews in FEIS. Fire Regime Reports and Syntheses will continue to be updated with the latest (2020) LANDFIRE data.
- **Fire Studies** are summaries of one or more fire research projects at a specific location. For example, Effects of wildfire on a riparian community in southeastern Arizona was published to complement Species Reviews on southwestern riparian trees.

FEIS publications have applications in fuels management, fire management, and postfire restoration. FEIS is used by managers in federal, state, and tribal land management agencies, NGO's, private landowners, university students and scientists, and the general public.

For more information, visit: https://www.feis-crs.org/feis/

Innovation and Organizational Learning Research, Development & Application

The Innovation and Organizational Learning Research, Development and Application (IOL) unit's mission is to foster a resilient workforce, advance innovation, and promote a culture of learning at the individual, group, and organizational levels within the U.S.D.A. Forest Service (USFS).

In October 2022, the Organizational Learning functional area released the Wildland Fire Meta-Review, 2007-2016, an examination of ten years of Agency fire-related accident, incident, and normal work data. With the release of the metareview, IOL set a path to spark conversations around 8 "Big" topics to further exploration and support organizational learning. With learning products including a 508-compliant, interactive PDF, audiobooks, Storymaps, and a webinar series, IOL has been receiving feedback that the products are being used to facilitate conversations about the Big 8 on units across the country. These conversations build understanding and help close the gap between work as perceived and work as carried out.

A 10-year review of accidents and incidents within the USDA Forest Service wildland fire system.

National Fire Decision Support Center (NFDSC)

The goals of the interagency National Fire Decision Support Center (NFDSC) are to build upon previous scientific achievements that 1) improve and implement new fire behavior prediction tools; 2) strengthen the science of fire management planning, response, performance, and accountability; and 3) advance the science, development, and dissemination of quantitative wildland fire risk analysis methods.

Research supporting the NFDSC focuses on operations research and decision science to support wildland fire decision making. Focus areas include, but are not limited to:

- **Fire Behavior Sciences**. Implement and support new fire behavior modeling that overcome limits of existing modeling tools.
- **Wildfire Risk Management Science.** Develop and apply risk analysis, economics, and decision science research to improve the scientific basis for wildfire management.
- **Fire System Performance and Analytics.** Develop applied research focused on the nexus of risk management, analytics, and systems thinking. Work toward a vision for fire management where tools support decisions and actions that are risk-informed, evidence-based, enriched with analytics, and aligned with long-term objectives.
- **Landscape Dynamics and Scenario Planning.** Build information systems and coupled models to address the gap in multi-scale decision support tools to prioritize and evaluate forest and fuel management investments.

For more information, visit https://firelab.org/collaborative-program/national-fire-decision-support-center-nfdsc

Wildland Fire Management Research, Development & Application (WFM)

The Wildland Fire Management Research, Development & Application program (WFM) is a joint effort between the USFS and the U.S. Department of Interior. WFM promotes the application of wildland fire scientific knowledge, develops and maintains decision support tools, and provides science application services to the interagency wildland fire organization, including real-time decision support for agency administrators managing wildfires.

The WFM RD&A has five focus areas:

- **Current Research.** Coordinate relevant and timely fire science research.
- **Decision Support Systems.** Develop and maintain fire management decision support systems that are risk-based, relevant, timely, and integrated. These include the Interagency Fuel Treatment Decision Support System (IFTDSS) and the Wildland Fire Decision Support System (WFDSS).
- **Risk Management.** Advance and develop emerging risk management science and research to support agency leadership and the wildland fire community.
- **National Fire Decision Support Center Collaboration.**
- **Application Development.** Develop applications and emerging technologies for existing and emergent agency and research priorities.

Current projects include developing WFDSS NextGen, and expanding and delivering user support for IFTDSS, which saw demand greatly increase in 2022 because of the National Prescribed Fire Review.

For more information, visit: https://wfmrda.nwcg.gov/

Conservation Education

FFS Conservation Education programs engage students and the public about wildland fire science

The Fire Lab provides tours, workshops, field trips, presentations, and educational curricula and materials to help increase public understanding of the science of wildland fire. Opportunities for in-person education and events began to open in 2022 after disruptions from the COVID-19 pandemic in 2020-2021.

In FY 2022, the Fire Lab's Conservation Education program reached nearly 3400 K-12th grade students and over 1000 adults. Many student activities utilized the FireWorks Educational Program, which consists of activities and hands-on materials to help students learn about the science of wildland fire. In addition, activities geared towards Native American students and adults were coordinated by FFS Tribal Liaison Dr. Serra Hoagland. The Fire Lab also hosted another successful seminar series featuring talks on a wide variety of topics surrounding fire science and management.

Students participate in a fire whirl demonstration in the burn chamber as part of a Fire Lab tour. Photo credit: Ian Grob

Other highlights included:

- In June 2022 the Fire Lab hosted a group of students from the University of Montana's Upward Bound program. This program, administered by the US Department of Education, provides access to higher educational opportunities for lower income students. Students were provided information about the Fire Lab's history and science along with a tour and live burning demonstrations.
- The Program welcomed Shibu Arens and Timothy VanReken, staff for US Senator Jon Tester (MT), to the Fire Lab in August 2022. RMRS Legislative Affairs Specialist Keith Grant and Dr. Sara Brown, FFS Program Manager, provided overviews of the research station and the FFS program, followed by live burning demonstrations and lightning talks by several scientists in the FFS and Human Dimension (HD) programs. The afternoon concluded with a lengthy roundtable discussion of issues surrounding fire management, fire science, and community engagement.
- In September 2022 the Fire Lab hosted a group from the Western Regional Air Partnership (WRAP), part of the Western States Air Resources Council (WESTAR). The group heard presentations on a variety of topics such as fire risk, fire ecology, and fire safety, followed by a tour of the facilities and live burning demonstrations.

FireWorks

The *FireWorks* Educational Program is an educational program designed to teach students in grades K-12 about the science of wildland fire. First developed in 2000, the program includes curricula of hands-on activities and trunks of materials for teachers to borrow and use in their classrooms. Students learn fundamental concepts of fire behavior and fire ecology in a variety of ecosystems.

FireWorks activities are used in classrooms, fields sites, festivals, and at the Fire Lab. Student field trips to the Fire Lab and other fire education outreach resumed in 2022 after a 2-year hiatus due to the pandemic. *FireWorks* is regaining its momentum after the slow-down and will once again offer a 2-day workshop in June 2023.

Students learn how wildland fires spread while conducting experiments from the FireWorks curriculum.
Photo credit: Olga Helmy

Educational activities for FY 2022 included:

- *FireWorks* activities with students and the public at the Fire Lab (two class field trips), four school classrooms, four festivals/fairs, and two school events. Together, these activities reached approximately 4,100 people.
- Updated older versions of the *FireWorks* trunks to reflect current curricula.
- Loaned *FireWorks* trunks to two schools, reaching approximately 100 students.
- Advised partners on *FireWorks* adaptations for other ecosystems and regions.
- Presented the *FireWorks* program at two conferences (Association of Fire Ecology Conference. 2022 Montana STEM Summer Institute).
- Staffed booth at the Missoula County Fair with Lolo National Forest. Approximately 200 booth visitors used *FireWorks* activities.

For more information, contact: Ilana Abrahamson at ilana.l.abrahamson@usda.gov

Seminar Series

FY 2022 marked the 24th year of the Fire Lab Seminar Series. The series provides a platform for Fire Lab employees and researchers and managers from throughout the world to present their work in an environment that encourages critical thought, the free exchange of ideas, and knowledge discovery. During the COVID-19 pandemic the seminar series was presented virtually, though an in-person option has again been offered in 2023.

The FY 2022 series covered a variety of topics informing wildland fire science, ranging from technological innovations to post-fire tree physiology. Presenters explored ecological perspectives on sagebrush landscapes, whitebark pine, the effects of wildfire on snow water storage and snowmelt, and the interaction of climate, changing fire regimes, and subsequent effects on wildlife. They discussed research related to fire spread and fire behavior, air quality, fire meteorology, landscape-level fuel treatments, and post-fire management effects on fuel loads. An analysis of home survival in the 2018 California Camp Fire was presented, and a panel composed of researchers from the Cal Poly Wildland Interface FIRE Institute discussed their efforts to address fire in the WUI.

The series included two panel discussions on the state-of-the-science on climate and wildland fire. Dr. Matt Jolly provided an international view of emerging technologies from the Fire Lab shared to support Latin American emergency responses to wildfire. Finally, wildland firefighter experiences with harassment and discrimination were explored from an organizational learning perspective focused on gender harassment and discrimination.

Upcoming seminars, along with an archive of seminar recordings, can be found at: https://www.firelab.org/project/fire-lab-seminar-series

Tribal College Student Support

In 2017, the FFS program established a permanent Tribal Liaison Officer position in-residence at Salish Kootenai College (SKC) on the Flathead Indian Reservation in Pablo, Montana. SKC is the only tribal college in the U.S. with a 4-year degree program in Forestry and blends technical curriculum with tribal cultural values. On average SKC hosts approximately 40% of the U.S. population of native students pursuing a forestry degree at any one point in time.

As the Tribal Liaison Officer/Biologist, Dr. Serra Hoagland serves as a role-model, mentor, and advisor to tribal students, not just at SKC but for several native students across the country studying natural resources.

For more information, contact: Dr. Serra Hoagland at serra.j.hoagland@usda.gov

Trainings

A critical aspect of the FFS Science Synthesis and Delivery mission is training. In 2022, FFS scientists continued to ensure that accurate science is incorporated into fire and fuels trainings for interagency fire managers nationwide. This is accomplished primarily through participation in the development and instruction of National Wildfire Coordinating Group (NWCG) courses, workshops presented at national and international conferences, and providing training on FFS applications and products. FFS scientists work closely with staff from the Northern Rockies Training Center and the Northern Rockies Fire Science Network to provide additional training opportunities to fire managers.

National Wildfire Coordination Group (NWCG) Course Support

FFS scientists support numerous NWCG courses as Science Advisors and Subject Matter Experts through course development and serving in course leadership positions as Steering Committee members, Lead Instructors, Unit Leads, or Instructors. These courses support the development and skills within the interagency fire community for various positions and career development.

In FY 2022, personnel from the FFS program supported the following trainings:

RX-301 Prescribed Fire Implementation

RX-341 Prescribed Fire Plan Preparation

RX-510 Advanced Fire Effects

S-290 Intermediate Wildland Fire Behavior

S-390 Fire Environment Assessment and Fire Behavior Estimation

S-482 Strategic Operational Planning

S-491 Intermediate National Fire Danger Rating System

S-495 Geospatial Fire Analysis, Interpretation and Application

Students participate in a fire training offered by NWCG.
Photo credit: USFS

FFS Research Focus Areas

Fire and Ecosystems

Climate change and human expansion into wildlands are exacerbating changes to vegetation and fuels from historic conditions. These changes affect biotic disturbances that interact with wildland fire. These interactions and stresses are changing contemporary fire regimes, degrading ecosystem resilience, and altering fuel hazard. Knowledge of fire effects and ecology in fire-dependent ecosystems is essential to develop fuel-related products, treatment alternatives, restoration strategies, and accurate forecasting of future conditions.

Fire Behavior

Fire behavior is the foundation for models and knowledge used by managers in prediction, planning, and training. Critical processes in fire behavior remain unexplained and thereby limit the accuracy and reliability of modeling and create uncertainty throughout the spectrum of fire management activities. Research products that expand knowledge and yield practical advances in modeling will profoundly improve the Forest Service's ability to manage fire and its effects for the benefit of natural resources and human communities.

Fire Management Systems

Decision support systems improve the effectiveness and efficiency of fire and forest management activities and increase the safety of planning and operations. Advances in information technology, data, and modeling mean that new systems can be designed to meet emerging needs and long-standing challenges, including the analysis of tradeoffs within fire management investments and between fire and land management activities (including fuel treatment and prescribed fire), as well as estimation of risk to highly valued resources.

Interdisciplinary

Wildland fire science includes interdisciplinary components that cross-cut several focal areas. Research disciplines such as meteorology and climate improve our understanding of the conditions that limit and promote wildland fire activity. Technologies such as terrestrial, airborne and spaceborne remote sensing platforms offer ways to map and explore components of the wildland fire environment. Finally, the creation of science application products is critical to transfer technology from research to operations and provide access to best available science.

Smoke Emissions

Wildland fires are a significant source of air pollution and can be a major hazard to public health. In addition, the threat posed to wildland firefighters who may be exposed to dense smoke is unresolved. Smoke management concerns are among the top impediments to prescribed burning. Wildland fires are major sources of greenhouse gases and carbonaceous particles which collectively have a significant impact on the climate system. Understanding the response of wildland fire emissions to climate variability and is crucial to assessing future air pollution and potential climate feedbacks.

For more information on all Fire Lab research projects, including archived and complete, visit: firelab.org/projects

Research Projects

Active or recently completed Fire, Fuel, and Smoke Program research projects

Changes in Fire Likelihood and Intensity Due to Climate Change

Projected changes in temperature, precipitation, and relative humidity are being used to estimate changes in fire regimes (including fire likelihood, size, and intensity) using simulation modeling (FSim) in the continental U.S.

Project Manager: Karin Riley

Climate Impact on the Fire Activity in North America

This project seeks to better understand the driving forces of fire activity from 2002 to the present.

Project Manager: Wei Min Hao

The Closing Gaps Project: Linking Remote Sensing, Advanced Fire Models and New Applications to Improve Prescribed Fire Science

The Wildfire Crisis Strategy calls for expansion of prescribed fire and fuel treatments using the best available science. The Closing Gaps project seeks to eliminate or reduce barriers to the use of best available science by collecting integrated datasets on prescribed burns, testing advanced fire models, and building capacity for managers to use these advanced tools.

Project Manager: Russ Parsons

The Effect of Fuel Break Network Geometry on Future Wildfire Interactions

This project is exploring how alternative implementation geometries for large scale fuel break networks effects interactions with wildfires over time.

Project Manager: Michelle Day

FastFuels: Modeling Fuels in 3D for Next-Generation Fire Models

Fuel treatments, prescribed fire, and disturbances such as beetle-kill present challenges for current fuels data and fire models. The FastFuels project addresses these challenges by providing a basis for modeling fuels with higher detail and by building connections to advanced fire models.

Project Manager: Russ Parsons

Fire Induced Tree Mortality

Accurate predictions of fire-induced tree mortality are needed for models used in planning, post-fire management, predicting future landscape dynamics, and feedback to the global carbon cycle. There are several active projects to improve our understanding of how fire kills trees and efforts to improve model predictions of fire-induced tree mortality.

Project Manager: Sharon Hood

For more information on all Fire Lab research projects, including archived and complete, visit: firelab.org/projects

Fuel Break Effectiveness for Discontinuous Fuels

High resolution sampling techniques are used to assess changing fire behavior to evaluate the effects of landscape scale natural and mechanical fuel treatments on wildfire within varying fuel and fire behavior classifications.

Project Manager: Dan Jimenez

Fuel break experiment at Konza Biological Research Station in Manhattan, KS. Photo credit: Dan Jimenez

Fuels and Potential Fire Behavior in Balsam Woolly Adelgid-impacted Forests

We are developing a product and methodology that allows rapid assessment of fuels and potential fire hazard in forests impacted by the non-native balsam woolly adelgid to better protect and improve the health of western America's high-elevation fir forests.

Project managers: Sharon Hood and Russ Parsons

Fundamental Wildland Fire Spread Research

Current operational fire behavior models do not describe heating and combustion processes, and physical models assume the fire spread processes of heat exchange and ignition without an experimental basis. FFS researchers and collaborators have developed a program of research for understanding how fire spread occurs with a focus on live fuels and active crown fire.

Project Managers: Mark Finney and Sara McCallister

Improved Fuel Moisture Models for Use in Gridded Forecast Systems

This project seeks to explore and evaluate the live and dead fuel moisture models used in the US National Fire Danger Rating System and to leverage these models to better inform complex, coupled fire-atmosphere model simulations.

Project Manager: Matt Jolly

Live Fuels: Key Processes Controlling Ignition, Burning Rate, and Fuel Consumption

This project explores how the physical, chemical, and thermal characteristics of live fuels contribute to variations in ignition and burning rates and subsequent consumption. This work will be used to improve live fuel consumption models that are used for prescribed fire planning and wildland fire response.

Project Manager: Matt Jolly

For more information on all Fire Lab research projects, including archived and complete, visit: firelab.org/projects

Lubrecht Fire-Fire Surrogate Study

This long-term study site in the Northern Rockies study examines 20+ year responses to thinning and prescribed burning treatments commonly used in dry, low-elevation forests of the western U.S. It is part of the National Fire & Fire Surrogate Study to determine how fuel and restoration treatments affect forest resilience to fire, insects, and drought.

Project Manager: Sharon Hood

Forest stands in the Fire-Fire Surrogate Study 15 years after fuel reduction treatments at the Lubrecht Experimental Forest, Montana. Photos were taken 5 years after a mountain pine beetle outbreak.

Mapping and Modeling Fuels and Fire at the Sycan Marsh, Oregon

The goal of this project is to advance capabilities for managers to plan and evaluate prescribed fires and fuel treatments as proactive strategies to successfully protect communities, enhance firefighter safety, and restore ecosystems.

Project Manager: Russ Parsons

Modeling and Forecasting Wildland Fire Ignition and Spread Potential

This project explores state-of-the-art ways to compute and deliver high resolution weather data analyses and forecasts, machine-learning based predictive modeling, and other derived metrics of wildfire hazard. It will inform the foundation of new systems such as the Fire Environment Mapping System (FEMS) and it will support future, cloud-based fire modeling systems. Finally, it will help meet Congressional mandates such the Dingell Act.

Project Manager: Matt Jolly

Morocco Fire Environment System

We are collaborating with the Moroccan National Agency for Water and Forests (ANEF) to develop datasets and tools to facilitate monitoring and forecasting of wildfire potential across the country. This involved direct collaborations with scientists and professionals throughout Morocco to build local capacity for wildland fire decision support.

Project Manager: Matt Jolly

For more information on all Fire Lab research projects, including archived and complete, visit: firelab.org/projects

National Wildfire Hazard Modeling with FSim

FFS research scientists have led the production of national spatial datasets of the probabilistic components of wildfire hazard, with datasets published previously in 2016 and 2020. In 2022, the Fire Modeling Institute continued this work in conjunction with FFS scientists and Pyrologix LLC to produce spatial datasets of burn probability and conditional fire intensity for the conterminous US, Alaska, and Hawaii from LANDFIRE 2020 fuels data. New data are expected to be published in 2023.

Project Managers: Greg Dillon, Mark Finney, Karin Riley, and Karen Short

Ponderosa Pine Restoration at Lick Creek

Lick Creek is the longest running fuel treatment and restoration study in the western United States. Through repeat photography and numerous publications, we show how fuels and vegetation have changed over the 25+ years since treatment and compare the effects of harvesting with and without prescribed burning.

Project Manager: Sharon Hood

Predicting Tree Growth and Beetle Susceptibility After Fire

This study examines 10–20-year effects of low- and mixed-severity fire on tree survival and growth, snag longevity, and bark beetle activity. Sites were established immediately post-fire to assess tree injury and survival. They are being revisited to determine long-term fire effects.

Project Manager: Sharon Hood

Pyrolysis and Combustion of Southeast Vegetation

Enhancing our understanding of pyrolysis and combustion of southeast US understory vegetation.

Project Managers: Wei Min Hao and Steve Baker

Smoldering Combustion Processes

Smoldering combustion carbon emission species and rates, and its effect on air pollution and ecosystems.

Project Managers: Wei Min Hao and Steve Baker

South American Regional Fire Program Fire Forecasting Component

This project seeks to evaluate and improve wildfire hazard and risk forecasting in Peru, Ecuador, Colombia, and Brazil. We work directly with forecast agencies in each country as well as wildland fire responders and decision makers to identify needs and potential improvements to these systems. This work will lead to improved predictive services and decision support capabilities throughout Latin America.

Project Manager: Matt Jolly

For more information on all Fire Lab research projects, including archived and complete, visit: firelab.org/projects

Support for National-Level Forest Service Wildfire Analyses

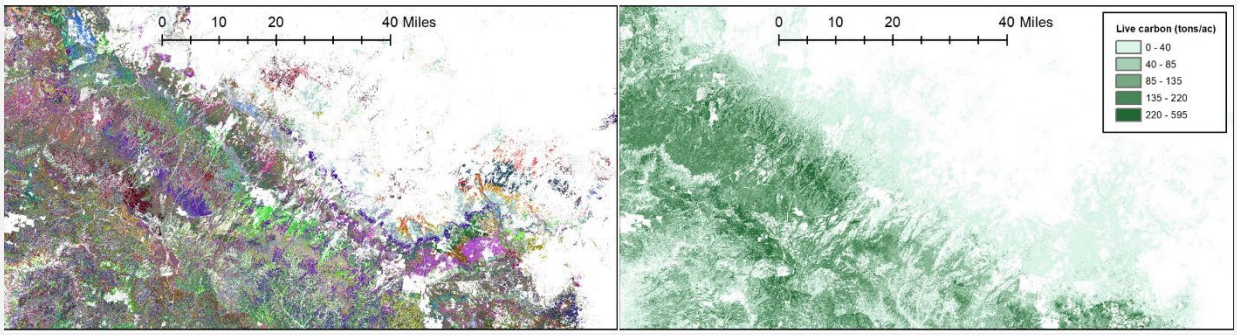
In FY 2022, the Forest Service was required to produce analyses of wildfire risk and exposure relative to infrastructure, drinking water supply, wildlife habitat, social vulnerability criteria, and other factors named in the Bipartisan Infrastructure Law, Inflation Reduction Act, and USDA Secretarial Memo 1077-044 on Climate Resilience and Carbon Stewardship of America's National Forests and Grasslands. Analysts from the Fire Modeling Institute were called upon by the Washington Office throughout the year to provide datasets and data processing and analysis expertise to support these efforts.

Project Manager: Greg Dillon

TreeMap: A tree-level model of the forests of the United States

The TreeMap 2016 dataset is a spatial model of the trees in continental US forests. It provides detailed spatial information on tree and forest characteristics, and summary information including forest type, number of live and dead trees, biomass, and carbon.

Project Manager: Karin Riley



Left image: Plot identifiers for a subset of the Mogollon Rim of Arizona. Each unique color corresponds to a different plot. Right image: Live tree carbon for the same subset of the Mogollon Rim.

Tree Mortality and Fuel Changes from an Extreme Drought and Bark Beetle Outbreaks in California

This study examined how the severe 2012-2016 drought and ensuing bark beetle outbreaks in California altered fuel loading and arrangement. We also investigated the factors influencing whether trees survived or died during the drought.

Project Manager: Sharon Hood

The US National Fire Danger Rating System Version 4.0

This project is developing innovative ways to improve the science and technology that form the US National Fire Danger Rating System. This includes continuous evaluation of fuel moisture models, fuel modeling and index calculations that form the foundation of the system, integration of NFDRS into analytical tools and operational websites, and the exploration of improved long-term drought metrics.

Project Manager: Matt Jolly

For more information on all Fire Lab research projects, including archived and complete, visit: firelab.org/projects

Wildfire Risk in the Sagebrush Biome

A quantitative wildfire risk assessment is underway for the sagebrush biome in the western US to inform investments in hazardous fuel treatments, including those intended to protect sage-grouse habitat.

Project Manager: Karen Short

Wildfire Risk to Communities

This project is a collaboration between Forest Service Fire and Aviation Management, the Fire Modeling Institute, and private partners Headwaters Economics and Pyrologix LLC. The project provides maps, charts, and information about community scale wildfire risk to all communities, counties, tribal areas, and states nationwide. In 2022 we added capability to search by tribal areas and produced data summaries to identify communities as "at risk" or having high or very high wildfire hazard potential for the new BIL-funded Community Wildfire Defense Grant program administered by Fire and Aviation Management.

Project Manager: Greg Dillon

Wildfire Risk to Forest Carbon

Datasets for forest carbon (TreeMap) and fire risk maps (FSim) were combined to estimate carbon released from fire at the scale of the continental U.S.

Project Manager: Karin Riley

Wildfires Caused by Firearms Use

Provides the first accounting of shooting-related wildfires in the U.S. based on empirical data. A newly approved fire-cause data standard should allow for better tracking into the future.

Project Managers: Karen Short and Mark Finney

Wildland Fire Smoke Sensors

Laboratory and field testing of air quality sensors to improve technologies and monitoring of wildfire smoke impacts on rural communities across the West.

Project Manager: Shawn Urbanski

Wildland Firefighter Safety Zones & Escape Routes

High resolution landscape scale spatial data is used to pre-identify potential wildland firefighter safety zones and escape routes by assessing potential fire behavior associated with vegetation cover and terrain.

Project Manager: Dan Jimenez

For more information on all Fire Lab research projects, including archived and complete, visit: firelab.org/projects

Applications and Products

Tools, apps, and datasets developed and/or maintained by the Fire, Fuel, and Smoke Program

[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. A new version is in development.

Project Managers: Faith Ann Heinsch and LaWen Hollingsworth

[BehavePlus Online Training Course](#)

Three online training courses have been developed on the use of BehavePlus to cover surface, crown, and prescribed fire behavior modeling. They can be accessed on the Wildland Fire Learning Portal.

Project Managers: Faith Ann Heinsch and LaWen Hollingsworth

[FastFuels: 3D Fuels for Next Generation Fire Models](#)

FastFuels combines existing fuels and spatial data with cutting edge modeling to generate 3D fuels data for use in advanced 3D fire models.

Project Manager: Russ Parsons

[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.

Project Manager: Duncan Lutes

[Fire and Tree Mortality Database](#)

The Fire and Tree Mortality database contains individual-tree records from prescribed fires and wildfires in the United States. The database includes records from 164,293 individual trees with records of fire injury (crown scorch, bole char, etc.), tree diameter, and either mortality or top-kill up to ten years post-fire. Data span 142 species and 62 genera, from 409 fires occurring from 1981-2016.

Project Manager: Sharon Hood

[Fire Weather Alert System](#)

The Fire Weather Alert System (FWAS) has been designed to warn on-the-ground firefighters of dangerous weather conditions in their area. Users set custom weather thresholds and the FWAS sends alerts via text message and email when those thresholds are exceeded.

Project Managers: Natalie Wagenbrenner and Jason Forthofer

For more information on all Fire Lab applications and products, visit: firelab.org/applications

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.

Project Manager: Matt Jolly

Fireshed Registry

The Fireshed Registry is an ArcGIS online portal that assembles spatial data on historic fuel treatments, wildfire risk, projections on extreme fire events, and fireshed priorities as implemented in the Wildfire Crisis Strategy.

Project Manager: Michelle Day

First Order Fire Effects Model (FOFEM)/SpatialFOFEM

FOFEM is a computer program developed to meet needs of resource managers, planners, and analysts for predicting fuel consumption, smoke emissions, soil heating and fire-caused tree mortality. SpatialFOFEM is a spatial implementation of the of the FOFEM model used for simulating landscape-scale fuel consumption, emissions, and fire-caused tree mortality.

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.

FOFEM & FuelCalc Project Manager: Duncan Lutes

FlamMap 6.2

FlamMap is a fire analysis desktop application that can simulate potential fire behavior characteristics, fire growth and spread, and conditional burn probabilities. FlamMap 6.2 was released in 2022.

Project Manager: Chuck McHugh

ForSys

ForSys is a scenario planning system that uses spatial optimization methods to design landscape management plans and prioritize investments to meet social and ecological objectives and constraints.

Project Manager: Michelle Day

For more information on all Fire Lab applications and products, visit: firelab.org/applications

ICS-209-PLUS

Research-ready compilation of all-hazards operational data 1999-2020. These situation-reporting data can be used to relate large-fire activity to weather, fuel treatment activities, firefighting response, and a range of socioeconomic impacts.

FS Project Manager: Karen Short

Interagency Fuel Treatment Decision Support System (IFTDSS)

The Interagency Fuel Treatment Decision Support System (IFTDSS) provides a system for planning fuel treatments to reduce risk to communities and other high value assets. It also enables application of prescribed fire to restore and maintain landscapes.

Project Management: WFM RD&A

Photoload

Photoload is a fuel sampling method designed to quickly and accurately estimate loadings for six surface fuel components using sequences of photographs.

Project Manager: Chris Stalling

Real-Time Forecasting of Wildfire Ignitions out to 7 Days

This comprehensive, georeferenced model predicts wildfire starts out to 7 days based on forecast weather and data on vegetation cover and recent drought history.

Project Manager: Ned Nikolov

Safe Separation Distance Evaluator (SSDE)

The Safe Separation Distance Evaluator is an interactive, open-access Google Earth engine-based tool that helps identify and evaluate potential safety zones anywhere in the U.S.

Project Manager: Daniel Jimenez

SnagHazard

A national map of estimated snag density and height, classified into four low to high hazard classes. The map is used operationally by firefighters for situational awareness.

Project Manager: Karin Riley

Spatial Database of U.S. Wildfires

A database of standardized and error-checked wildfire records for the period 1992-2020 from federal, state, and local wildfire reporting systems.

Project Manager: Karen Short

For more information on all Fire Lab applications and products, visit: firelab.org/applications

TreeMap
A spatial model of forest inventory data for the continental U.S. For each 30x30 pixel, users can obtain the best-matching Forest Inventory Analysis plot number and the accompanying list of trees, as well as estimated number of live and dead trees, live and dead biomass, and live and dead carbon.
Project Manager: Karin Riley

Wildfire Hazard Potential
The wildfire hazard potential map is a raster geospatial product that can help to inform evaluations of wildfire hazard or prioritization of fuels management needs across very large landscapes.
Project Manager: Greg Dillon

Wildfire Risk to Communities
Wildfire Risk to Communities is a free, easy-to-use website with interactive maps, charts, and resources to help communities understand, explore, and reduce wildfire risk.
Project Manager: Greg Dillon

WildfireSAFE
WildfireSAFE applications provide simplified access to an advanced suite of fire weather and fire products. WildfireSAFE was designed to increase firefighter and fire manager situation awareness, enhance risk mitigation in wildland fire operations, and support the greater interagency fire community in all phases of fire management.
Project Manager: Matt Jolly

Wildland Fire Assessment System
The Wildland Fire Assessment System (WFAS) collects and displays fire danger information for the United States.
Project Manager: Matt Jolly

Wildland Fire Assessment System Lightning Maps
These products give the user different views of lightning ignition/fire potential both before and after the day's lightning-producing thunderstorm activity. The map-based products available include 1) Potential Lightning Ignitions, 2) Lightning Ignition Efficiency, 3) Observed Dry Lightning/Estimate Rain, and 4) Observed Dry Lightning/Dryness.
Project Manager: Paul Sopko

For more information on all Fire Lab applications and products, visit: firelab.org/applications

Wildland Fire Decision Support System (WFDSS)

The Wildland Fire Decisions Support System (WFDSS) assists fire managers and analysts in making strategic and tactical decisions for fire incidents. WFDSS integrates the various applications used to manage fire incidents into a single system, which streamlines the analysis and reporting processes.

Project Management: WFM RD&A

Wildland Fire Investment Planning System (WFIPS)

The WFIPS system is intended to conduct risk-based analysis of fire management activities and wildfire outcomes for alternative investments in Preparedness, Hazardous Fuels, and Large Fire Suppression. Analysis occurs at user-specified local, regional, and national scales for all lands and all agencies.

Project Manager: Mark Finney

WIMS Development and Support

Weather Information Management System (WIMS) is the application that hosts the U.S. National Fire Danger Rating System (NFDRS), used by all federal and most state fire management agencies for assessing seasonal fire severity across the nation.

Project Manager: Matt Jolly

WindNinja and WindNinja Mobile

WindNinja is a tool that computes spatially-varying wind fields for wildland fire and other applications requiring high-resolution wind predictions in complex terrain.

Project Manager: Natalie Wagenbrenner

For more information on all Fire Lab applications and products, visit: firelab.org/applications

The Research Continues

The Rothermel Fire Spread Model: A 50-year Milestone in Fire Research

An earlier version of this article was published April 13, 2022, at Inside the Forest Service

2022 marked the 50th anniversary of one of the most important milestones in wildland fire research history. In 1972, Richard C. "Dick" Rothermel published his pioneering modeling work. It remains the most widely used tool for wildfire behavior modeling, not only in the United States, but throughout the world. The "Rothermel Model" is embedded in dozens of computerized fire behavior systems used for fire management planning, training, and operational predictions.

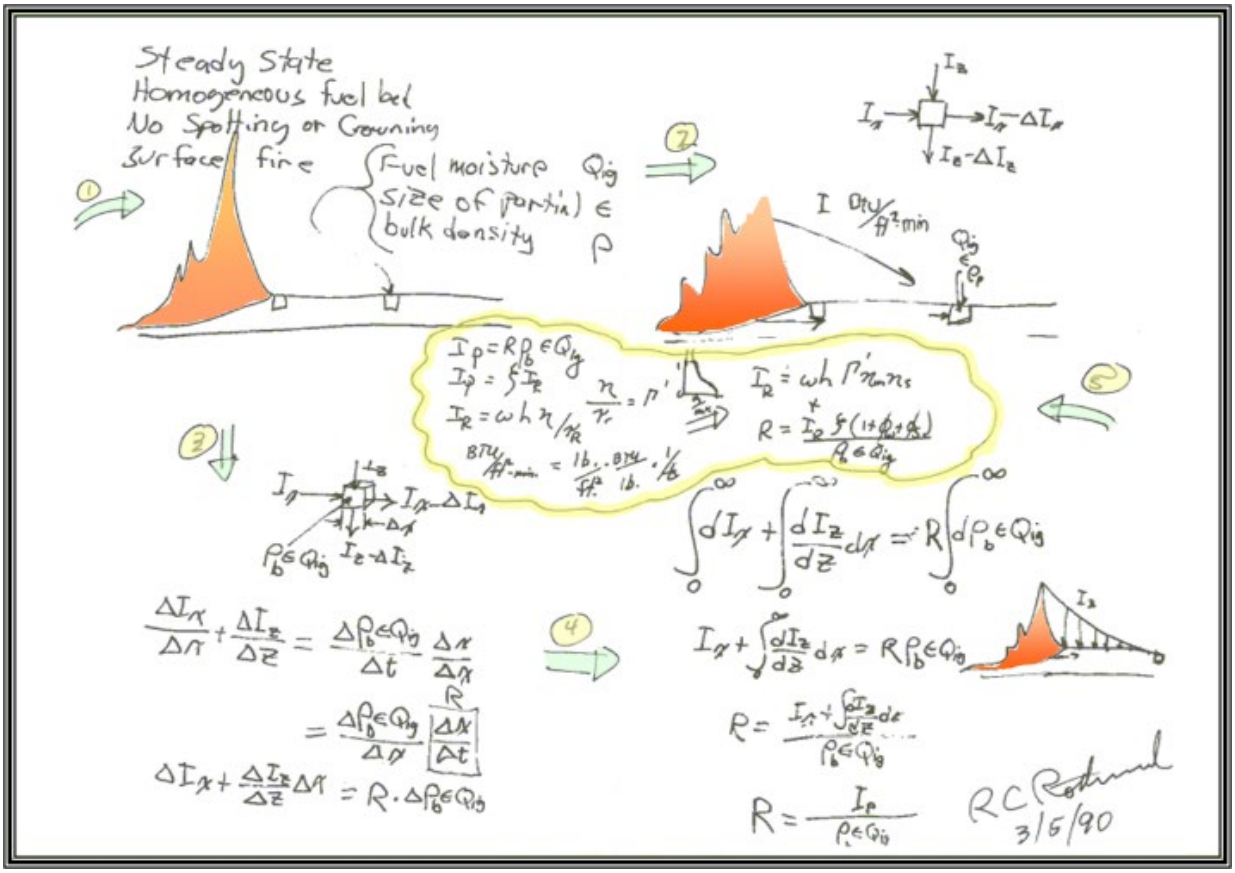
Dick Rothermel in 2022.
Photo credit: Ian Grob

Rothermel's paper, "A Mathematical Model for Predicting Fire Spread in Wildland Fuels," detailed the structure and function of a quasi-empirical model for calculating the steady state spread rate and intensity of a wildland surface fire. The achievement was based on a decade of experimental and theoretical work by Rothermel and his numerous colleagues in the Fire Physics Project at the Missoula Fire Science Laboratory, then called the Northern Forest Fire Laboratory. The model was implemented immediately after publication in 1972 to determine indices of potential fire activity and behavior for the new National Fire Danger Rating System (NFDRS) – and it is still used in this capacity today. However, a wider range of uses for this revolutionary model were also envisioned in those early days, including localized fire behavior prediction, large-scale simulation of wildfires, and planning for fuel treatments and prescribed burning. Applications for all these needs, and many more, have come into operational use in the succeeding decades.

The broad and continuing success of the Rothermel Model is partly due to the practical input requirements and the reasonable predictions that are robust to uncertainties. With wildfire predictions restricted to the steady state spread of a linear heading fire, the complexity of fuel and environmental conditions could be greatly simplified. Fuels are described with stylized fuel descriptions called "Fuel Models" that span a wide range of highly complex vegetation conditions. Wind and topographic slope effects in any combination are readily obtained for spatial fire modeling. This model and its input requirements have established many standards used throughout the wildland fire world, the origins of which are now largely taken for granted. It is interesting to contemplate how fire behavior science and fire management would look today without this foundational work.

In 2022, to mark the 50th Anniversary of the Rothermel Spread Model, Dick Rothermel was honored with an award for Outstanding Contribution to Fire Science at the International Conference for Forest Fire Research in Coimbra, Portugal. Senior Scientist Mark Finney also sat down with Dick to discuss the research that led to the landmark publication of his model. You can view the interview here.

Looking forward to the next half-century, we will be facing escalating challenges in managing wildfires and their impacts. To meet these needs, a large and growing worldwide research community continues to pursue both improved knowledge of fire physics and practical advances in fire modeling. Despite enjoying immense advantages in technology, the enduring difficulties of wildfire science and associated development of practical tools routinely reminds us of the significance of achievements by Rothermel and his team in producing the spread model 50 years ago.



Sketch of the Rothermel Fire Spread Model.

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