Missoula Fire Sciences Laboratory

Fire, Fuel, and Smoke Science Program

Research Highlights

2011

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CONTENTS

Cutting edge work in wildland fire research

The Fire, Fuel, and Smoke Science Program (FFS) of the Rocky Mountain Research Station is located at the Missoula Fire Sciences Laboratory in Missoula, Montana. The Program's world-renowned scientists, technicians, and support staff conduct international, cutting-edge work in wildland fire research from fundamental lab-based research in fire physics to large-scale field research in fire ecology. Specific research activities are centered toward understanding wildland fire processes, terrestrial and atmospheric effects of fire, and ecological adaptations to fire. Research also develops associated knowledge tools and applications for both managers and scientists. Our mission is to improve the safety and effectiveness of fire management by creating and disseminating the basic fire science knowledge, tools, and applications for scientists and managers.

What's at the Fire Lab?

In addition to its leading scientists and support personnel, the Missoula Fire Sciences Laboratory features state-of-the-art burn chambers and wind tunnels, comprehensive laboratory facilities, extensive computing resources, and novel field instrumentation that provide a unique and creative work environment for conducting innovative wildland fire research.

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RICH HISTORY OF FIRE RESEARCH

Fifty Years of Wildland Fire Science

Predicting fire behavior and fire effects—whether to manage ecosystems more effectively or to protect human lives and property—is a constant challenge to land managers, particularly now with projected changes in climate. In September 2010, the Missoula Fire Sciences Laboratory (or "Fire Lab") celebrated 50 years of helping managers continue to meet these kinds of challenges in the field.

The questions studied and technologies applied at the Fire Lab have continually evolved since 1960, but the Lab's original focus on developing a greater understanding of fire and using the best technology to communicate that knowledge to land managers has been a way of life for Fire Lab scientists, technicians, and support staff since 1960. Working with research partners from around the country, including universities and colleges as well as other government agencies, Fire Lab research continues to focus on these challenges—from understanding the interactions of fire and climate to protecting the wildland-urban interface.

Researchers at the Missoula Fire Sciences Lab build on past knowledge, while developing and adapting new technologies to open entire new fields of inquiry. For example, current research projects include everything from investigating relationships between insects, fire and climate at the stand scale, to creating management guides for ecosystem restoration of lodgepole pine forests of Montana.

Our researchers are mapping the potential for high severity wildfire in the western United States, studying the impact of thinning methods of fire behavior in Alaskan forests, and developing methods for characterizing fire behavior in long leaf pine. We are also investigating firefighter safety, looking at safety zone exposure to convective heat on steep slopes, as well as examining how firefighter safety zones are affected by slope.

Results from lab and field-based research are synthesized in diverse forms, including models, systems, publications, and presentations to help managers understand how best to manage wildfires, keep firefighters and homeowners safe, and learn how fire affects our forests and the atmosphere. For example, working with the assumption that pictures speak louder than words, researchers are currently developing fire characteristics charts to help communicate the results of surface and crown fire behavior models, while others are developing mapping techniques using simulation modeling and satellite imagery. In addition, we are expanding management goals by publishing large overview reports on the effects of fire on cultural resources.

The following pages highlight just a few of the Fire Lab's recent accomplishments. Together with all the other research currently underway at the Fire Lab, they add up to improving the safety and effectiveness of fire management through the creation and dissemination of basic fire science knowledge to meet today's challenges, and the challenges that lie ahead.

DISCOVERING THE FUNDAMENTALS OF FIRE

Despite the many operational models used in fire management, the physical processes responsible for fire spread are not well understood. To address this need, researchers are testing basic assumptions to develop a better understanding of fire spread under various conditions.

Laboratory experiments conducted to date suggest that radiant intensities found in wildland fires are not sufficient to ignite fine fuel particles (needles, grasses) because of cooling by free and forced convection, but that flame convection provides critical heating of particles to ignition. Moreover, the edges of turbulent flames from controlled laboratory experiments vary at frequencies slower than about 10 Hz and fuel particle ignition occurs after some period of intermittent heating and cooling at fine scales, which is highly non-linear. However, researchers have been able to model these using a technique called One Dimensional Turbulence (ODT).

Researchers have also discovered that ignition of wood depends on a critical rate of converting solid mass to combustible gas similar to other substances (e.g. plastic), and that ignition depends on heat flux and wind flow, providing an improved definition of ignition and flammability limits. Finally, the research has documented that live fuels (e.g., conifer foliage) can burn at moisture contents many times higher than dead fuels because they release moisture explosively, compared to slow diffusion in dead fuels, and they contain large amounts of non-structural carbohydrates. This research suggests a completely new approach to understanding and modeling fire spread based on an experimentally supported theory, creating new opportunities for developing models that can be used for fire management applications.

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LINKING CHEMISTRY, MOISTURE CONTENT AND COMBUSTION CHARACTERISTICS OF LIVE FUELS

Living plants form a large component of the wildland fuel complex, resulting in fires that can burn erratically and intensely. And yet, little is known about how or why living plants burn. Live plants generally have moisture contents ten times higher than comparable dead fuels, yet they still burn readily during a typical fire season. Until recently, most if not all of the studies comparing chemistry and combustion characteristics have been inconclusive. Both moisture content and chemistry are known to vary seasonally, but little has been done to compare seasonal changes in chemistry and moisture content to the ignition potential of live fuels.

To better understand how and why living plants burn, and under what conditions, researchers are examining how the time-to-ignition of live foliage changes as a function of both moisture content and leaf chemical make-up. Historically, researchers have attributed foliar moisture changes to “drying” of the vegetation, but research to date indicates that leaf chemistry is a strong driver of the “apparent” changes in measured live fuel moisture.

Indeed, researchers have demonstrated that these changes are primarily driven by changes in sugar and fat content of the foliage and have little to do with changes in the actual moisture in the fuels. These results have helped researchers better understand live fuel combustion, and will be incorporated into fire behavior models for more effectively predicting fire spread and intensity characteristics across a landscape.

Additionally, some of this information is already being used to guide live fuel sampling strategies for monitoring live fuel conditions across the United States.

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MEASURING THE CHEMICAL COMPONENTS OF SMOKE

Wildland fires are a significant source of pollutants, many of which present significant regulatory challenges. The production, transport, and transformation of primary and secondary pollutants from fires must be better understood in order to minimize and mitigate their impact on human health, economic activity, scenic integrity, and ecosystem resiliency.

Project results will be used to improve smoke modeling tools, air quality planning, regulation and forecasting.

Air quality regulators and land managers employ smoke modeling systems to predict, evaluate, and manage the impact of fire emissions on air quality. However, the current scientific understanding of smoke emissions and smoke plume chemistry suffers from significant knowledge gaps that have hindered the development of reliable smoke modeling systems. A team of partners, including the Fire Labs in Missoula, MT and Riverside, CA , has recently completed a multi-year smoke chemistry research project. Project results will be used to improve smoke modeling tools, air quality planning, regulation and forecasting.

In the laboratory component, researchers collected vegetation samples from the Southeast and Southwest, and burned them in the Missoula combustion facility, measuring the composition of initial emissions from the burning vegetation. Researchers observed emissions associated with high-efficiency flaming combustion (e.g., CO_2, SO_2,NO_X, HCl, HONO) and those associated with lower-efficiency smoldering combustion (e.g., CO, CH_4, NH_3, NMOC).

Researchers also sampled fresh emissions from 14 prescribed fires at or near the locations where the fuels for the lab experiment were collected. Fresh smoke emissions measurements provide emission factors (EF) to estimate the quantity of pollutants emitted by fires, and can be used to improve widely used smoke modeling tools. The smoke aging measurements are being used to develop improved smoke chemistry models which may greatly improve the ability to predict the air quality impact of fires and facilitate the development of successful strategies for air shed management.

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UNDERSTANDING THE IMPACTS OF MOUNTAIN PINE BEETLE

Decades of fire control left behind overly-dense forests, allowing mountain pine beetles to rapidly infest ponderosa and lodgepole pine forests across much of the West. Recent periods of drought make trees even more susceptible to insect outbreaks. Fire Lab Scientists are on the cutting edge of research focusing on the relationship between mountain pine beetles and fire.

Mountain pine beetle is an endemic insect that affects pine species throughout the Rocky Mountain West, where single-age stand conditions and warm climate patterns have led to a large-scale outbreak.

Once infested, trees die, turning their needles red. Scientists have debated the effect these beetle-killed trees might have on fire behavior, but little is yet known. For example, beetle-killed trees lose their needles over time, and once they all have dropped, crown fire danger largely disappears. But researchers do not know how long that takes, or how long the trees remain at risk for crown fire initiation and spread. Moreover, if these trees have a canopy fuel moisture lower than uninfested trees, it will lead to increased crown fire activity.

Initial findings indicate that a substantial number of needles stay on beetle-infected trees for up to 4 years. Researchers are now working with managers to identify trees 1-5 years after a pine beetle attack, with the goal of producing a standard reduction for each year since the attack. This will then be applied to estimations of crown fuel loads generated from standard canopy calculations, helping identify how long beetle-infested stands remain a fire hazard.

Researchers have also investigated the average crown moisture content of beetle-killed trees before losing their needles. Since these trees have ten times less crown moisture content than healthy, green trees, forests with a large number of beetle-killed trees are at significantly higher risk of surface fires igniting the crown. Crown fires cannot be directly suppressed by ground resources, and are very dangerous to both firefighters and communities. Such low crown fuel moisture levels could also result in beetle-killed trees contributing to spotting much further ahead of the fire.

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MAPPING SPATIAL VARIABILITY OF WILDLAND FUEL

Wildland fuel can be directly manipulated to achieve management goals, such as restoring ecosystems, lowering fire intensity, minimizing plant mortality, and reducing erosion. However, many find it difficult to measure, describe, and map wildland fuels because of the great variability over space and time, and few have attempted to quantify this variability to understand its effect on fire spread, burning intensity, and ecological effects.

This study investigated the spatial variability of a number of fuel characteristics across major surface and canopy fuel components in northern Rocky Mountain forest and range fuelbeds. Researchers measured surface fuel characteristics of loading, particle density, bulk density, and mineral content for eight fuel components and canopy bulk density, fuel load, and cover to describe canopy fuel variability. Surface fuels loadings were estimated using a combination of visual assessment, piece length, and direct collection methods on plots established within the grid. The research team then described the spatial distribution of fuel characteristics along with their variance using statistical analysis tools.

This study will have profound implications for fire management in that the measured many conventional fuel products and analysis inappropriate for expected future mechanistic fire behavior simulations. Findings and data from this study can be used to map fuel characteristics, such as loading, at finer scales to accommodate the next generation of three dimensional fire behavior prediction models. New fuel classifications can be developed to describe the variability of fuel across the different sizes and types of fuels in the fuelbed.

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Big Hole Valley (BV)
BLM land near Bannack, MT

Colville Forest (CF)
State land near Colville, WA

Lubrecht Forest (LF)
Lubrecht Experimental Forest, MT

Ninemile (NM)
Lolo National Forest, MT

Silver Mountain (SM)
BLM land near Cedar City, UT

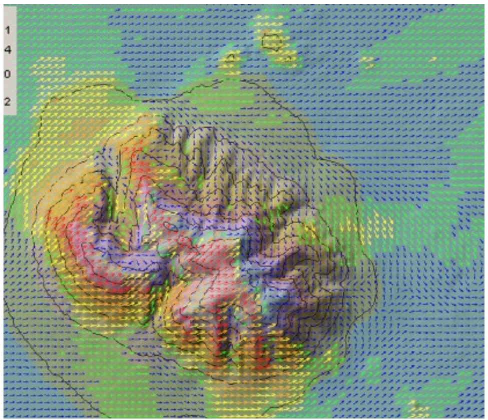
Tenderfoot Forest (TF)
Tenderfoot Experimental Forest, MT

MEASURING THE WIND

Spatial wind variability is a major factor influencing wildland fire behavior, but the accuracy of short-range fire behavior predictions has been limited by the lack of spatially resolved surface wind flow information.

To address this need, researchers have developed two wind simulation tools (WindWizard and WindNinja) to resolve wind flow over mountainous terrain at a scale of 100 - 300 feet. To test the accuracy of these models, however, researchers need to compare the simulations against measured wind data. Unfortunately, few data sets of microscale wind flow in complex terrain at the required resolution are available. Therefore, researchers are working to document weather data through intensive instrumentation campaigns at several field locations.

Using over 50 cup and vane anemometers, sodar and radar profilers, weather balloons, sonic anemometers and NWS weather stations across the mountain and the region, researchers are collecting weather data to validate and improve the models. Preliminary findings suggest that, as expected, terrain has a significant impact on wind speed and direction.



The resulting data will be organized into an online database that other researchers and wind model developers can access for validation purposes. Researchers expect to complete the study in 2011.

For more information, contact: Jason Forthofer, jforthofer@fs.fed.us

Figure 1

Figure 2

RESTORING THE HEALTH OF OLD-GROWTH FORESTS

This study investigated whether or not fuel treatments can help restore a healthy, resilient character to old-growth ponderosa pine and western larch forests in western Montana, while reducing the probability of uncharacteristically severe wildfire. Figure 1 shows a stand before treatment. Figure 2 is after thinning and prescribed fire. A publication of results is in preparation.

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MANAGEMENT GUIDE FOR MULTI-AGED LODGEPOLE PINE FORESTS PRODUCED

Lodgepole pine is one of the most widely distributed conifers in North America. Throughout much of its range, the fire regime is mixed-severity rather than stand replacement, resulting in patchy and often multi-aged lodgepole pine forests. Fire exclusion, however, can reduce multi-aged lodgepole pine heterogeneity.

To determine the most appropriate treatment to create multi-aged lodgepole pine stands, Fire Lab scientists implemented a combination of thinning and prescribed burning treatments on the Tenderfoot Creek Experimental Forest, MT. They measured changes in fuel loading, tree density, and tree mortality due to fire, finding that even-distribution thinning alone, or combined with prescribed fire, results in extremely low overstory density.

Based on this research, the investigators produced a guide to help managers determine potential effects of harvesting and prescribed burning in lodgepole pine to create multi-aged stands.

For more information, see: Hood, S. M.; Smith, H. Y.; Wright, D.; Glasgow, L. In Press. Management Guide To Ecosystem Restoration Treatments: Multi-aged Lodgepole pine forests of Central Montana, USA. Fort Collins, CO: U.S. Forest Service, Rocky Mountain Research Station.

SAWGRASS FUEL MODELS

Sawgrass (*Cladium jamaicense)* grows in the flooded marshes and glades of southern Florida and can quickly dominate a landscape. Sawgrass grows in areas flooded most of the year, but it can burn in any month, regardless of water depth. This fire-adapted species forms dense 6-12 foot stands that slowly disappear as native bushes, exotic species and human changed water tables alter its native range. While frequent fire eliminates competitors keeping sawgrass on the landscape, its fire behavior and fuel characteristics are not well described. Only one National Fire Danger Rating System (NFDRS) fuel model attempts to describe it, but it does not include the live fuel component that can dominate this fuel type. For that reason, managers struggle to make current models match conditions on the ground. Using sensors developed by Fire Lab investigators, researchers tracked radiant and convective heat flux, rate of spread, and fuel loadings throughout prescribed fire units.

With this information, researchers intend to develop a well characterized data set for evaluation of fire models, and to develop a custom fuel model that describes fire intensity and rate of spread across a range of loadings. While evaluation of the data is still underway, preliminary results indicate that the build up of dead material at the high-water mark was the driving factor in fire behavior, even with high relative humidity and low wind speed.

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Loxahatchee National Wildlife Refuge, Florida, prescribed fire in sawgrass with specialized sensors developed by Fire Lab researchers

MODELING EFFECTS OF CLIMATE CHANGE

Climate changes are projected to have a major influence on landscape patterns and biotic communities, either directly through increased species mortality and shifts in species distributions, or indirectly from factors such as increased wildfire activity and extent, shifting fire regimes, and pathogenesis. High-elevation landscapes are particularly sensitive to climatic changes and are likely to experience significant impacts under projected future climates.

Researchers, studying the effect of potential climate change on whitebark pine, a keystone and foundation species, found that projected climate changes could have a significant negative impact in the study landscape (the McDonald watershed in Glacier National Park). Loss of whitebark pine communities may have important ecological implications including reduced snowpack accumulation and retention and changes in the timing and amount of surface water runoff. Moreover, whitebark pine produces seeds that are an important food source for over 110 animal species, including the endangered grizzly bear, so shifts in wildlife habitat suitability and food availability may occur.

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While managers cannot predict future climate conditions, it is very likely that the climate will be different than it is today. The best opportunities for conserving key vegetation communities into the future may be to proactively manage under current conditions. For example, a restoration program that selects for high levels, 20 percent and above, of rust resistance in whitebark pines will likely increase the presence of these keystone species on the McDonald watershed and similar northern Rocky Mountain landscapes. As climate conditions change, continued research may highlight additional opportunities for restoration under future environments.

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DOUBLING KNOWLEDGE ON FIRE AND EASTERN INVASIVE PLANTS

The Fire Effects Information System (FEIS) recently completed a 2-year project to double the information available on invasive plants in the eastern United States. While knowledge syntheses do not create new field data, they do create new understandings of existing data by bringing the results of all studies on a topic together in one location, summarizing them, comparing results, and analyzing differences.

The project also included a quantitative analysis of knowledge gaps in the scientific literature regarding eastern invasive plants and fire, showing that information on fire and invasives is often lacking. Fire-related topics such as immediate fire effects, postfire responses, and influences on fire regimes were covered by field observations or experiments in fewer than half of the 61 species reviews completed in this project; 9 of these reviews contained no observation-based information on any fire topic.

By synthesizing information on fire and invasive plant species and compiling information on knowledge gaps, this project helps improve the quality, efficiency, and cost effectiveness of fire and invasive species management.

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CREATING NEW ECOLOGICAL MONITORING UTILITIES

Federal mandate and agency policy require ecological monitoring of treatments by all agencies. Despite these mandates, monitoring data are often not collected or, if they are, the results are not stored in a way that allows analysis of the results and the sharing of data.

In an effort to help managers collect and store monitoring data in a consistent and accessible format while meeting monitoring mandates, researchers have developed an ecological monitoring utility, known as FFI (FEAT/FIREMON Integrated), that integrates two widely used fire effects applications. An interagency group of managers assisted in the development of FFI so it would meet their specific needs, resulting in a monitoring application developed by and for land managers, which has helped ensure its success. In one application, land managers can enter, update, store, display, summarize and analyze monitoring data specific to their needs.

FFI has been used by managers in numerous projects that include multiple agencies and partners.

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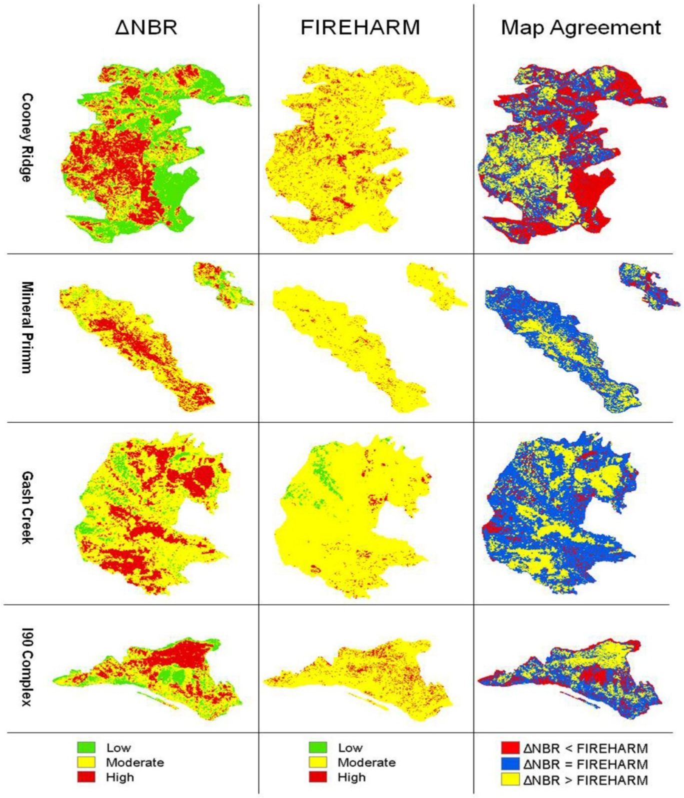
BURN SEVERITY MAPPING

Although burn severity maps derived from satellite imagery provide a landscape view of fire impacts, fire effects simulation models can provide spatial fire severity estimates and add a biotic context in which to interpret severity. In this project, researchers evaluated two methods of mapping burn severity in the context of rapid post-fire assessment for four wildfires in western Montana: (1) an image-based burn severity mapping approach using the Differenced Normalized Burn Ratio, and (2) a fire effects simulation approach using the FIREHARM model. Sixty-four plots were used as field reference. The image-based approach was moderately correlated with percentage tree mortality but had no relationship with percentage fuel consumption, whereas the simulation approach was moderately correlated with percentage fuel consumption and weakly correlated with percentage tree mortality.

Burn severity maps produced by the two approaches had mixed results. Both approaches had the same overall map agreement when compared with a sampled composite burn index, but the approaches generated different severity maps. While both approaches have limitations and more research is needed, these techniques have the potential to be used synergistically to improve burn severity mapping capabilities of land managers, as well as quickly and effectively meet rehabilitation objectives.

For more information, see Karau, EC and Keane RE. 2010. Burn severity mapping using simulation modeling and satellite imagery. International Journal of Wildland Fire. 19(6):710-724.



Satellite-derived and model-simulated maps of burn severity for the four fire areas. Column 1: DNBR (Differenced Normalized Burn Ratio). Column 2: FIREHARM Burn Severity. Column 3: Difference map showing discrepancy and agreement between DNBR and FIREHARM burn severity maps (red means DNBR severity was lower than FIREHARM severity, blue means the maps are in agreement, and yellow means DNBR severity was higher than FIREHARM severity).

MAPPING THE POTENTIAL FOR HIGH SEVERITY WILDFIRE

While tools exist to assess the severity and ecological effects of wildfires after they burn, land managers also need new tools that easily and quickly forecast the potential severity of future fires. Researchers understand much about how climate, fuels, and topography influence fire extent, but their effects on burn severity are little understood. To meet this need, Fire Lab investigators are developing a set of 98-ft (30-m) resolution, wall-to-wall continuous maps for the conterminous western United States that will document the potential for high-severity fire under different climate and weather scenarios. Working with combined burn severity observations from more than 7000 past fires, researchers are now extrapolating across entire landscapes to predict the potential for high-severity fires in the future. Based upon their analyses thus far of wildfires in the southwestern and northwestern parts of United States, they are finding that while

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an area burned in wildfires is greatly affected by climate, local topography and fuels appear relatively more important to the ecological effects of those fires. That said, weather and climate still play an important role in burn severity. For example, topography and fuels may have less influence on burn severity when conditions are especially hot, dry and windy (i.e., fire burns more indiscriminately under more extreme conditions), a pattern that researchers expect to document in their final predictive maps.

For more information, visit: www.firelab.org/research-projects/fire-ecology/128-firesev. For an overview of the mapping work, see: Dillon, G.; Morgan, P.; Holden, Z. 2011. Mapping the potential for high severity wildfire in the western United States. Fire Management Today. 71(2): 25-28.

A technician collects burn severity field data on the 2009 Big Pole fire in Utah, spring 2010. Data from plots such as this will be used to assess accuracy of predictive maps.

A FIRE SEVERITY CLASSIFICATION

Fire severity classifications have been used extensively in fire management over the last 30 years to address specific environmental or ecological impacts of fire on fuels, vegetation, wildlife, and soils in recently burned areas. Most of these classifications are comprised of highly subjective, simplistic classes tailored to meet specific problems or needs. Almost all reduce fire severity to subjective classes of "low," "moderate," or "high." Fire Lab researchers used computer simulation burning on over 115,200 fuel beds to formulate a method of classifying burn severity that would quantitatively relate the physical properties of fire (intensity) to fire effects (depth of burn, biomass consumption, temperature reached at depth, etc.) under several different moisture scenarios.

The strength of this classification process is that it begins quantifying potential fire effects from pre-burn fuel variability and explores the physical relationships of fuels with fire.

After constructing the fuel beds to represent a variety of compositions and burning them under 10 moisture scenarios, researchers found that nine classes of fire severity could easily describe the fire effects obtained from simulation burns. The classes had unique ranges in biomass consumption, fire residence time (i.e., burning from "flashy" to long-burning fires), fire intensities, and depth and temperatures of burns. The nine-classes could also be verified with an actual field dataset and with discriminant analysis.

The strength of this classification process is that it begins quantifying potential fire effects from pre-burn fuel variability and explores the physical relationships of fuels with fire. It has predictive potential and is a first step toward a more quantitative, objective, scalable approach to predicting fire severity from surface fuels and other on-site parameters. In addition, the classes are being used to develop fire severity keys within the FIRESEV project and can be used to make burn severity estimates from prescribed fire plans or for planning fuel reductions.

This research has been submitted to the International Journal of Wildland Fire for publication. For more information, contact: Pamela Sikkink, psikkink@fs.fed.us

RISK IN THE WILDLAND-URBAN INTERFACE

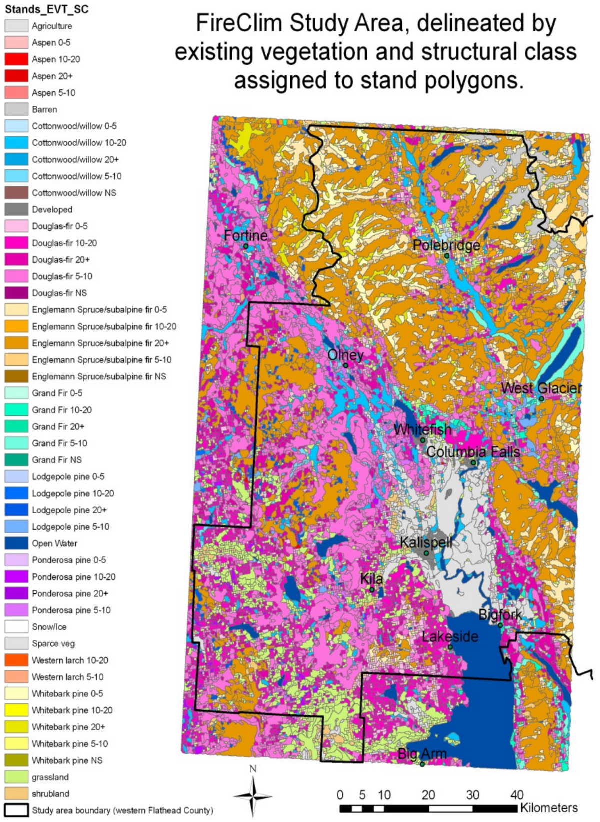
Future changes in climate and land use have the potential to increase the risk of wildfire in the wildland-urban interface. Understanding how management activities affect wildfire risk is key to planning for this uncertain future.

With support from the National Science Foundation and in partnership with researchers at the University of Missouri, Deakin University in Australia, USGS, and others, Fire Lab researchers used FireBGCv2, a fully integrated GIS-based, mechanistic ecological modeling system, to model future wildfire risk in Flathead County, Montana. Land managers from multiple ownership types (federal, state, private, non-profit, tribal) participated in stakeholder panels to offer advice on setting up the model and were included in the decision making on setting model parameters. This initial stakeholder involvement promoted a better understanding of the modeling effort by all concerned, as well as helping to ensure an increased likelihood of stakeholders using the results in future management decisions.

The FireBGCv2 model was used to simulate vegetation, fuel, and wildland fire dynamics over a fifty-year study period. Incorporating Forest Inventory and Analysis (FIA) data, LANDFIRE data, and actual field plots as parameters for the model, researchers used the model outputs to generate future burn probabilities at ten-year intervals. Researchers then incorporated these burn probabilities into an economic risk analysis model to estimate residential property damage from wildfire.

The results of this study demonstrate the challenges facing wildland managers in the face of climate change and provide a framework for adaptively managing future wildfire risk in the wildland-urban interface. By providing the community with a model for how to make wildfire-related decisions under alternative climate change and economic growth futures, the findings can help provide information on how future residential development and land use policy are likely to influence future wildfire risk.

For more information, contact: Robin Silverstein, rsilverstein@fs.fed.us or visit: http://www.firelab.org/firebgcv2-fireclim


FireClim Study Area, delineated by existing vegetation and structural class assigned to stand polygons.

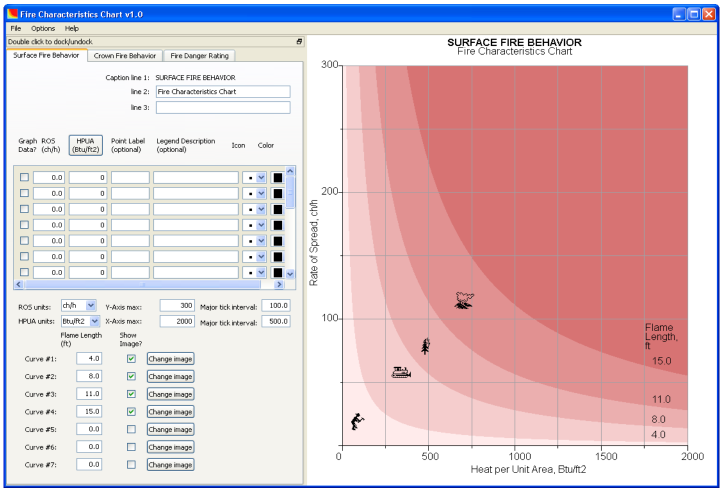
DO YOU BEHAVE?

The BehavePlus fire modeling system produces tables, graphs, and simple diagrams of modeled fire behavior, fire effects, and fire environment, and has become an established tool for many fire and fuels management applications. For example, BehavePlus is used for a range of applications including wildfire prediction, prescribed fire planning, and fuel hazard assessment, as well as communication, education, and training. Indeed, recent surveys conducted by independent researchers indicate that BehavePlus is the most widely used computerized fire system in the U.S.

And the system continues to evolve. For example, Fire Lab researchers have developed a supplemental computer program to create fire characteristics charts that present primary fire behavior characteristics (rate of spread, flame length, heat per unit area), aiding in communication and interpretation of fire behavior (modeled or observed). This new program creates charts that are much easier to use and interpret. But even through BehavePlus is widely used, and continues to be adapted, it currently needs an update (BehavePlusPlus?) to integrate the multiple fire behavior, fire effects, and fire danger rating systems. Researchers are currently looking at ways to generate basic fire modeling building blocks in the form of a library of mathematical code. This will facilitate resolving internal differences among existing systems, will provide an improved means of incorporating new research results, and will aid development of both web and desktop applications. Fire and fuels managers would undoubtedly welcome systems that are developed to meet their needs in the form of complementary components with a consistent modeling foundation, user interface, look and feel, and graph and report generators.

For more information, see:
Andrews, Patricia L.; Heinsch, Faith Ann; Schelvan, Luke. 2011. How to generate and interpret fire characteristics charts for surface and crown fire behavior, 2011, Gen. Tech. Rep. RMRS-GTR-253.

Andrews, Patricia L. 2010. Do you BEHAVE? – Application of the BehavePlus fire modeling system. In: Proceedings of 3rd Fire Behavior and Fuels Conference; 2010 October 25-29; Spokane, WA. Birmingham, AL: International Associa-



Caption line 1: SURFACE FIRE BEHAVIOR
line 2: Fire Characteristics Chart
line 3:

Graph Data?	ROS (ch/h)	HPUA (Btu/ft2)	Point Label (optional)	Legend Description (optional)	Icon	Color
☐	0.0	0			▪	■
☐	0.0	0			▪	■
☐	0.0	0			▪	■
☐	0.0	0			▪	■
☐	0.0	0			▪	■
☐	0.0	0			▪	■
☐	0.0	0			▪	■

ROS units: ch/h
Y-Axis max: 300
Major tick interval: 100.0
HPUA units: Btu/ft2
X-Axis max: 2000
Major tick interval: 500.0

	Flame Length (ft)	Show Image?
Curve #1:	4.0	☑
Curve #2:	8.0	☑
Curve #3:	11.0	☑
Curve #4:	15.0	☑
Curve #5:	0.0	☐
Curve #6:	0.0	☐
Curve #7:	0.0	☐

LANDSCAPE FIRE AND SUCCESSION MODEL

In coming years, wildland fire management will face increasingly difficult challenges such as climate change, fire exclusion impacts, and wildland-urban development, and require new, innovative means to address them. Field studies, while preferable and reliable, will be problematic because of the large time and space scales involved. Therefore, landscape simulation modeling will have more of a role in wildland fire management as field studies become untenable.

To meet this need, researchers have developed a new mechanistically complex, spatially explicit landscape fire and vegetation research tool to explore landscape and ecosystem responses to climate change. This new model, called FireBGCv2, simulates the effects of a wide range of management activities designed to create resilient and sustainable landscapes and incorporates several types of stand dynamics models into a landscape simulation platform.

FireBGCv2 can be used to simulate effects of potential alternative treatments to determine the most effective fuel reduction or ecosystem restoration strategy. Novel treatments can be simulated to determine resultant short- and long-term effects on a diverse array of ecosystem elements, and fire hazard and risk can be simulated to prioritize areas for treatment and to design the most effective treatment prescriptions. FireBGCv2 can also be used to approximate historical or future landscape conditions, and to update broad-scale digital maps and inform future sampling strategies for assessing change.

The inherent design of FireBGCv2 can be used by researchers to identify areas of possible research and to prioritize possible research directions. And most importantly, FireBGCv2 can be used to explore fire, climate, and vegetation interactions; quantify spatial and temporal dynamics of fire regimes; and describe potential fire dynamics under future climates and land management strategies to provide critical information that can help managers mitigate potential adverse effects.

For more information, see:
http://www.firelab.org/research-projects/fire-ecology/139-firebgc or Keane, Robert E.; Loehman, Rachel A.; Holsinger, Lisa M. 2011. The FireBGCv2 landscape fire and succession model: a research simulation platform for exploring fire and vegetation dynamics. Gen. Tech. Rep. RMRS-GTR-255. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 137 p.

DETERMINING THE EFFECTS OF FIRE-INDUCED WATER TEMPERATURE ON FISH COMMUNITIES

Wildland fire affects native fishes in the Rocky Mountain West, removing riparian vegetation, increasing direct solar radiation to the stream and leading to warmer summer water temperatures. Many native fish such as bull trout evolved with fire so are resilient to fire's effects. However, this resiliency has been reduced through stream habitat loss and degradation and the invasion of nonnative fishes (e.g., brook trout and brown trout) that better tolerate warmer water temperatures.

Therefore, forecasting the long-term effects of climate change and fire on water temperatures and native fish populations requires an understanding of fire dynamics, including size, distribution, frequency, and severity. With the University of Montana, the Fire Lab is using a landscape fire succession simulation model (Fire-BGCv2), linked to a stream temperature model, to predict bull trout persistence and changes in fish communities in Montana's East Fork Bitterroot River basin. Using model predictions, researchers will then evaluate potential thresholds in fire risk and the scales at which to expect recovery under various climate and fire regimes.

The partners' goal is to develop comprehensive information for understanding what fire and landscape characteristics pose higher risks to bull trout. For example, researchers expect the probability of bull trout persistence to vary as a function of increasing fire frequency, magnitude, and severity. If so, their key questions will be: (1) where to best focus bull trout conservation efforts (e.g., higher elevation areas where stream temperatures may be cooler?) and (2) whether fuel treatment alters outcomes. The research team also anticipates identifying thresholds at which the frequency of an area burned becomes detrimental to bull trout, and evaluating which factors (e.g., fire severity, fire size, vegetation, or fuels) result in large-scale, long-term changes in fish communities.

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Male bull trout in the East Fork Bitterroot River basin. Photo: Aubree Benson, Forest Service.

EFFECTS OF FIRE ON CULTURAL RESOURCES

The National Historic Preservation and Archaeological Resource Protection Acts require managers to protect cultural and archaeological resources for current and future generations. Numerous other acts direct agencies to manage fuels and fire to protect people, resources and property. Since fire can have a significant impact on cultural and archaeological resources, managers need access to knowledge about fire management, particularly in culturally resource-sensitive areas. To meet this end, researches from the Fire Lab, U.S. Forest Service National Forest System, National Park Service, and Simon Fraser University collaborated to synthesize best practices and provide a scientific foundation for managers and cultural resources specialists to protect and manage cultural resources for fire.

Currently in press:
Ryan, K.C.; Jones, A.T.; Koerner, C.H.; Lee, K.M., eds. In press. Wildland fire in ecosystems: Effects of fire on cultural resources. Gen. Tech. Rep. RMRS-GTR-42-vol.3. Fort Collins, CO: U.S. Forest Service, Rocky Mountain Research Station.

ASSESSING WILDFIRE RISK TO HUMAN AND ECOLOGICAL VALUES

For federal land management agencies, a national-scale assessment of wildfire risk offers a consistent means of understanding and comparing threats to valued resources and predicting and prioritizing investments in management activities to mitigate those risks. An actuarial approach to risk is well suited to strategic planning in fire and land management because it integrates fire probabilities with the consequences. Such quantitative risk assessments are still relatively new to wildland fire, in part because of the difficulty associated with reliably estimating burn probabilities and variability in fire behavior. Other challenges involve the estimation of economic or ecological impacts produced by the physical fire behaviors.

To address these challenges, scientists at the Missoula Fire Lab, in partnership with other researchers, have developed a simulation system designed to estimate the probabilistic components of wildfire risk across the conterminous US and evaluated its performance against historical records. Close agreement between simulated and historical fire size distributions suggests that fire sizes are determined by the joint distributions of spatial opportunities for fire growth (dependent on fuels and ignition location) and the temporal opportunities produced by conducive weather sequences.

Building on burn probability and intensity data, along with maps of highly valued resources, researchers have developed a quantitative geospatial wildfire risk assessment tool.

This research demonstrates a practical approach to using fire simulations at very broad scales for operational planning and, perhaps, ecological research. Data from fire simulations have been mosaicked to create a generally seamless national burn probability and intensity dataset for use in national wildfire decision support applications and to create national maps of wildfire potential.

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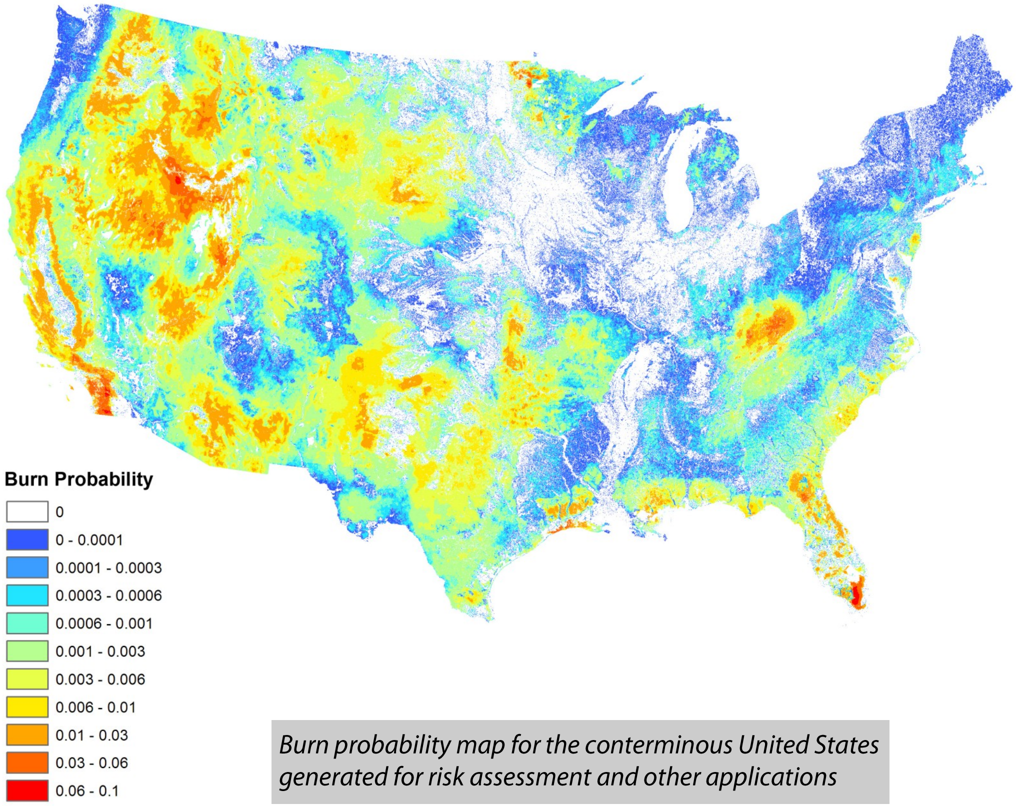

Burn probability map for the conterminous United States generated for risk assessment and other applications

MEASURING WILDFIRE SMOKE IN URBAN AREAS

The Earth's atmosphere is multi-layered, particularly during the daytime, with atmospheric pollutants accumulating in the lowest part of the atmosphere known as the Planetary Boundary Layer. This concentration is variable but tends to be higher in urban environments, where it can influence human health and affect a number of atmospheric phenomena, such as visibility, air quality, cloud formation, radiation balance, photochemical processes, and regional climate. Thus, urban boundary-layer meteorology has become an issue of concern in recent years.

During the last decade, large wildfires have resulted in significantly higher concentrations of fire-related pollution in California, affecting human health and air quality. To understand and solve this critical environmental issue, researchers need to understand the boundary layer structure through analysis of the distribution and dispersion of the pollutants near the ground. To quantify the variation, ground-based remote-sensing lidar (Light Detection And Ranging) is the most appropriate instrument, but the multiangle scanning mode of the lidar developed for wildfire applications cannot be used in urban conditions due to safety concerns. Therefore, researchers have modified their data retrieval technique, developed for the scanning lidar, and adapted it for measurements in urban conditions. This retrieval technique allows reliable measurements in the presence of different layers at the top the boundary layer, an application which has proven to be both simple to use and reliable in the California field tests. During the same study, researchers investigated the diurnal cycle and the influence of the ocean on the Planetary Boundary Layer. Onshore convective heating produces a low pressure with respect to the air over the ocean, which induces circulation. This atmospheric circulation process leads to a layering of pollution that can also be monitored by lidar.

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SIMULATING FIRE WEATHER

Fire Program Analysis (FPA) uses different weather scenario streams for each Fire Planning Unit. Each stream is spatially independent of the others, so there is no sense of coherence among the various locations. And yet, the regional coincidence of high or low fire danger can create difficulties in strategic planning and resource allocation. To capture the regional nature of weather and fire danger, Fire Lab researchers are currently working on a simulation method that reflects the spatial correlation observed in nature. The method will be incorporated in FPA at a future date, once testing and validation occur.

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FIREFIGHTER SAFETY AND SLOPE

All wildland firefighters must create safety zones where they can evacuate to in an emergency situation. These safety zones are one of the last lines of defense for a firefighter, but terrain and fuels can make it difficult to predict how large the area must be to properly protect personnel. Steep slopes promote rapid fire spread uphill because of the large convective flow of warm air upslope in front of the fire. At present, only radiative heat is considered in safety zone design. Convective heat is more difficult to model because it is highly dynamic in time and space. But new research uses an advanced fluid dynamics fire behavior model, FDS, to quantify convective heat exposure on slopes and with winds, with the goal of helping refine standards for firefighter safety zones and assess hazardous conditions. Preliminary work has found thresholds for weather, slope, and fuel conditions that keep convective columns close to the slope surface.

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1910 FIRES

The 1910 fires in western Montana and northern Idaho received much publicity, particularly the August 19-21 spread event (or "big blowup"). To better understand the fire's behavior, Fire Lab researchers examined weather data and reconstructed measures of Palmer Drought Severity Index (PDSI), Keetch-Byram Drought Index (KBDI), Energy Release Component (ERC), and Pacific Decadal Oscillation (PDO) to assess local and regional fire danger related to fuel conditions and to examine regional and continental scale measures of drought in 1910 in the northern Rockies.

Reconstructed measures of PDSI clearly illustrate drought conditions during the months leading up to and during the 1910 fire season. However, PDSI for the month of August were more severe in later fire seasons (e.g., 1919, 1934, 1988, 2000, and 2003) and over a much broader geographical extent. KBDI trends illustrate the early season dryness that occurred in 1910 but, again, KBDI trends have been higher in other years. For example, in 2003, KBDI values from July-October were much higher than those for the same period in 1910. Researchers also compared calculated ERC values from 1910 to later fire seasons to display and compare the 1910 season to other recent extreme years in the northern Rockies. Measures of ERC were higher in 1910 from May to mid-July when compared to 1988, 2000, and 2003. However, these years had higher ERC values from mid-July to October. An examination of PDO indicates a relatively cool (negative phase) period in 1910, especially when compared to the period 1980 to the present.

Many eyewitness accounts describe the winds during August 19-21, 1910 as "hurricane" or "cyclonic in nature." However, available hourly wind data recorded at Weather Bureau Offices operating in the region at the time indicate that peak recorded wind speeds during this period ranged from 20-26 mph, the exception being Lewiston, Idaho, which recorded peak wind speeds on these dates ranging from 38-42 mph. It is highly likely that winds near the fire were much higher as a result of fire-induced down drafts, fire whirls, and mass fires. This research brings some clarity to the mythology of the 1910 fires using data available at the time but enhanced with the knowledge we have gained since 1910 in fire behavior, weather and climatology.

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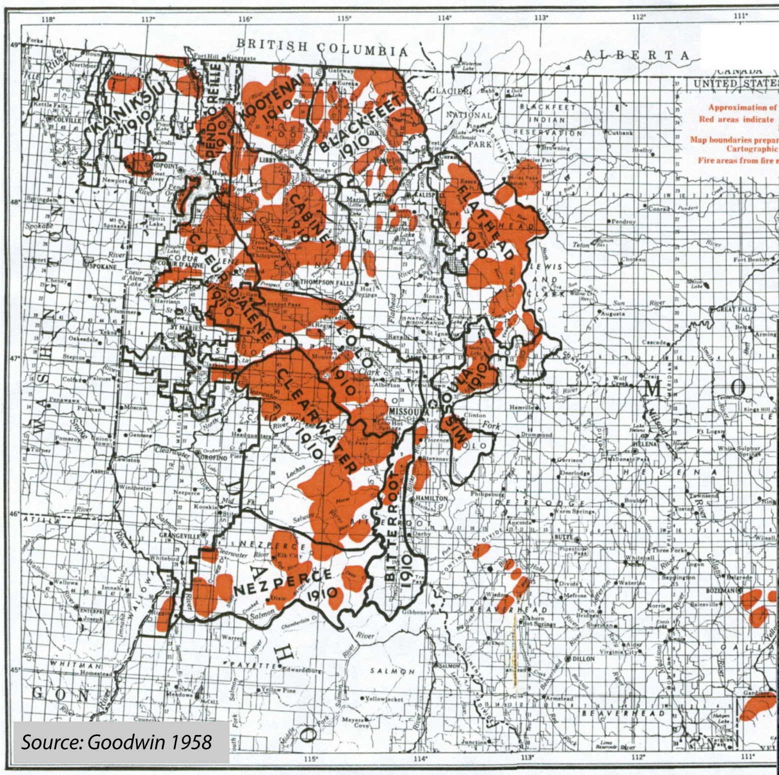
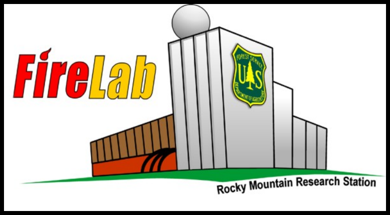


Source: Goodwin 1958

Map shows area burned by the 1910 Fires.



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