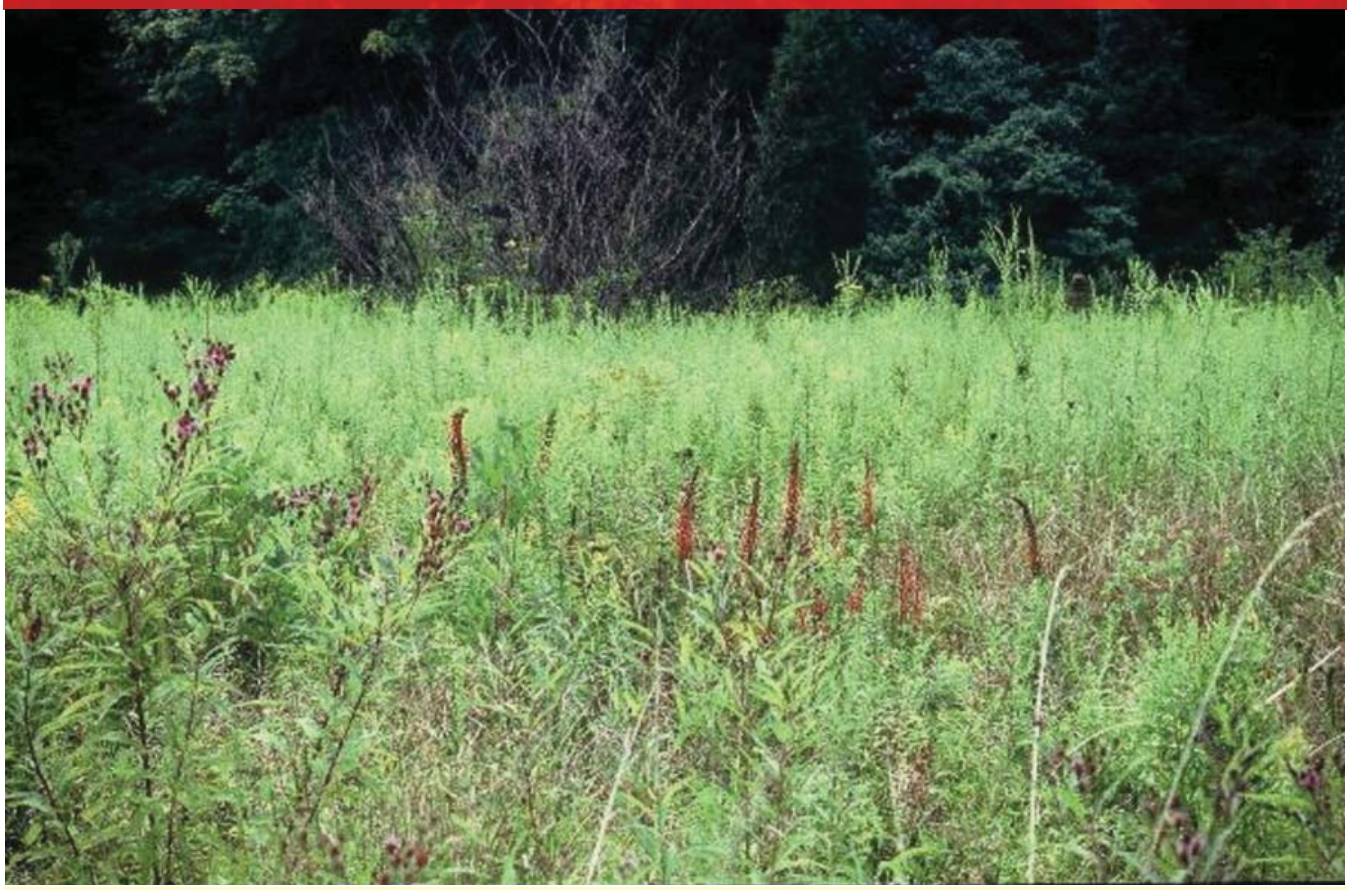
Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS



Proof of the restorative power of fuel treatments: three months after a prescribed burn in the Mark Twain National Forest in Missouri, cardinal flowers and ironweed thrive. Credit: Megan York-Harris and the USDA Forest Service.

Introducing FuelCalc: A New Tool that Helps Turn Static Inventory Data into Actionable Information

Summary

Fuel and fire managers perform fuel treatments to manage and restore ecosystems and protect resources. In order to plan effective fuel treatments that accomplish objectives, managers need to analyze fuel conditions and document the expected fire behavior and fire effects both before and after fuel treatment. To help accomplish these goals, a new software tool named FuelCalc was created. FuelCalc facilitates use of a wide range of inventory data and fuel characteristics to help calculate fuel quantities and qualities to estimate potential fire behavior, fire effects, and smoke production. By linking with a number of existing software systems and databases, FuelCalc provides a one-stop information resource to help managers make efficient, well-informed decisions regarding fuel management and treatment alternatives and their potential consequences in terms of direct effects on fuels and predicted effects on fire behavior and fire outcomes.

Key Findings

- FuelCalc 2.0 simulates the effects of specific fuel treatments and potential fire behavior and is available through the Missoula Fire Lab Website: http://firelab.fire.org.
- Managers produce the documentation needed to comply with the National Environmental Policy Act (NEPA) and support their fuel treatment decisions.
- Users can now convert inventory data into fuel qualities and quantities.
- FuelCalc accepts user-entered data and links with FEAT-FIREMON Integrated (FFI) to ease data import. FuelCalc also creates export files for the Stand Visualization System (SVS), First Order Fire Effects Model (FOFEM), NEXUS, and the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS).

Capturing data and calculating fuels

It's simple: fire needs fuel to burn. In the wild, this fuel typically consists of combustible plant-derived material such as grass, plants, shrubs, trees, exposed roots, dead woody debris, litter, and duff. As these fuels accumulate, land managers perform fuel treatments to help lower fire intensity, manage and restore ecosystems, and protect watersheds and communities.

Part of this responsibility includes assessing fuel treatment effectiveness as well as providing the necessary data to support fuel management decisions. Specifically, fire and fuel managers and federal agencies must comply with National Environmental Policy Act (NEPA) by preparing a detailed statement that supports fuel treatment decisions, their environmental impacts and treatment alternatives. But gathering the required information and converting it into a usable format is not always a quick or easy process. Existing fire behavior models and fuel treatment programs can help, but are typically not sophisticated enough to pull from various inventory data resources and generate the outputs needed to calculate fuel characteristics and quantities, estimate potential fire behavior, and simulate fuel treatments prior to implementation.

To improve this process, researchers developed FuelCalc, a comprehensive, user-friendly computer tool that first started out as a spreadsheet in 2001. Initially created by Joe Scott for the National Park Service and funded by the Joint Fire Science Program (JFSP), FuelCalc.xls had limited distribution and was designed to calculate fuel loads, create custom fuel models, and compute crown and surface fuel potential indices.

Fuel managers also needed a custom computer program or spreadsheet to convert the down woody fuel piece counts to fuel load, sampled using the planar intersect method. The planar intersect method, often called Brown's transects, is a sampling method where a measuring tape is laid along the forest floor and pieces of dead woody fuel are tallied if they pass through the vertical, six-foot sampling plane as defined by the measuring tape. One such conversion program, also called FuelCalc, was maintained by Duncan Lutes at the Missoula Fire Lab.

Elizabeth Reinhardt at the Missoula Fire Sciences Lab created yet another prototype of FuelCalc to be used as a canopy fuel quantification tool. Using the same method as the Forest Vegetation Simulator – Fire and Fuel Extension (FFE-FVS), this prototype was much simpler to use if temporal simulation of fuel dynamics was not needed. Reinhardt's prototype was applied by the Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) fuel staff and helped quantify canopy characteristics and enabled the creation of nationwide maps of canopy characteristics to model fire behavior.

In the Plumas National Forest of California, a worker removes conifers with less than 8 inches diameter at breast height (dbh) as part of an aspen stand enhancement project. Credit: Linnea Hanson and the USDA Forest Service.

Where fuel treatments and information meet

The ability to make well-informed decisions hinges on having access to high-quality information. According to the 1998 Joint Fire Science Plan, "managers need better information on the distribution and amount of fuels across vegetation types, as well as the impacts of these fuel structures and changing fire regimes on fire hazard, potential fire severity, and ecosystem structure and function." FuelCalc 2.0 helps accomplish just that, by enabling access to the specific inventory data that fuel and fire managers need to calculate fuel characteristics and to determine the appropriate fuel treatment methods.

In the Gila National Forest of New Mexico, a prescribed burn is performed to help lower the risk of high severity wildfire, reduce or reverse woody encroachment into ponderosa parkland and mountain meadow types, increase the herbaceous understory and promote re-sprouting of tender shoots of shrubs and trees. Credit: Jeff Rivera and the USDA Forest Service.

National in scope, FuelCalc 2.0 was released in 2010 and combines all of the functionality previously created, such as fire modeling, planar intersect calculations, and canopy fuel quantification. Replacing the prototype versions, FuelCalc 2.0 has greater distribution among the fire management community, provides a flexible interface, and offers enhanced capabilities that help characterize a wide range of fuel strata as well as simulate potential effects of fuel treatments — capabilities that were not available in a single tool until now.

Catering to a diverse user group including local- and regional-level fuel management specialists, FuelCalc can help users:

- Pull data from FFI or enter their own raw data and convert it into fuel quantities and qualities.
- Calculate surface fuel loads, fire behavior fuel models — both standard and custom — and fuel characteristics, which in turn can be used to model fire behavior, fire effects, and smoke production.
- Simulate the effects of various fuel treatments on fuel characteristics and fire behavior in support of fuel management planning and implementation, then use that information to make a decision on whether, where, and how to treat a fuelbed.

Principal Investigator Elizabeth Reinhardt stated, "FuelCalc enhances the ability of managers to design fuel treatments to achieve particular objectives, and to get direct estimates of fuel treatment effects, including how much biomass or wood volume they will generate, how much smoke will be produced if prescribed fire or pile burning is involved, what the characteristics of the treated stand and fuel bed will be, and what fire behavior to expect if the site burns post-treatment. All those pieces of the puzzle were available before, but they were not well integrated."

Evolved from a simple spreadsheet, FuelCalc 2.0 now provides the functionality needed to simulate fuel treatment effects and potential fire behavior.

FuelCalc step-by-step

Each FuelCalc project consists of fuel inventory data, tree inventory data, and model settings that describe fuel treatments and calculation options for one or more sample plots. The FuelCalc fuel calculation and simulation process includes the following sequential steps:

1. Fuel/vegetation inventory data
2. Fuel/vegetation characterization
3. Fuel treatment simulation
4. Fire potential simulation

Fuel/vegetation inventory data

Using standard techniques and methods, fuel and vegetation data are inventoried and then entered, edited, or imported into FuelCalc. For each sample plot, FuelCalc requires specific information including slope steepness, aspect, elevation, and location. The number of sample plots is unlimited for each project, however, the basic application of FuelCalc is at the individual plot level with summaries available for the stand level.

Fuel/vegetation characterization

Next, the fuel and vegetation inventory data from the above step is used to calculate fuel and vegetation characteristics for the initial condition. FuelCalc recognizes 2,018 unique tree species as well as 2,897 outdated tree species codes, and helps map the outdated codes to the currently accepted code for the species. Fuel types are quantified as ground, surface, piled, and canopy fuels:

- **Ground fuels:** refers to all fuelbed components whose load can be estimated as the product of depth and bulk density, including duff, leaf litter, lichen, and moss. By measuring duff depth, FuelCalc enables users to estimate duff load, which is essential to smoke management, carbon balance, soil heating, and site productivity applications.
- **Surface fuels:** come in a wide variety of forms and typically consist of grass, shrub, and herbaceous fuel and dead and down woody debris. With FuelCalc, surface fuel inventory can be provided by Brown's planar intersect method for

woody fuels, Burgan and Rothermel's surface fuel inventory method for grass, shrub, and litter fuel, and Hardy's slash pile inventory method for pile biomass estimation. Linkages are provided to key available fire behavior models, or custom fire behavior models can be created and tested with NEXUS or BehavePlus.

- **Piled fuels:** after thinning, fuels such as branches, shrubs, and leaves are piled by hand or machine. FuelCalc then uses Hardy's method of inventorying piled fuels to determine pile volume, shape, packing ratio, mass, and density.
- **Canopy fuels:** typically the aboveground portion of a plant community, canopy fuels include foliage, stem, and branch biomass. In FuelCalc, the latest techniques are used to estimate canopy fuel characteristics such as canopy bulk density, canopy fuel load, and canopy base height.

Fuel treatment simulation

Once the fuel characteristics have been defined, FuelCalc simulates how the fuel and vegetation will be affected by various fuel treatments, such as thinning, pruning, piling and burning and broadcast burning. In addition, FuelCalc provides a standard and custom fire behavior fuel model for the post-treatment fuelbed, enabling immediate calculation of fuel treatment effects on projected fire behavior.

Fire potential simulation

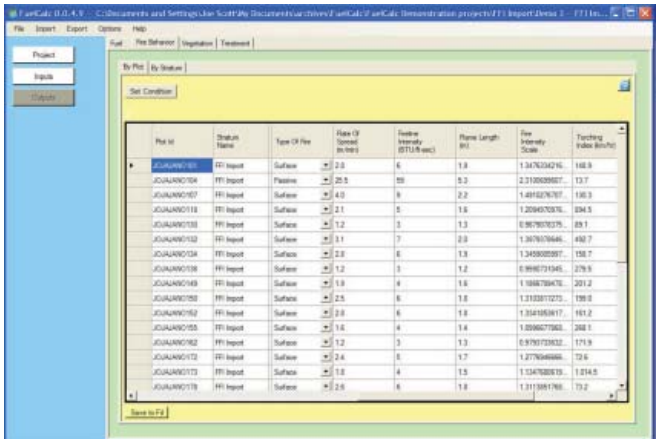
To simulate fire behavior potential in FuelCalc, users must enter basic inputs including wind speed, spread direction, wind direction, and weather scenario. FuelCalc then uses the NEXUS fire behavior processor to calculate the potential fire behavior characteristics of the resulting treated fuel complex, and the FOFEM fire effects model to estimate fuel consumption, tree mortality, and smoke.

Plugging into other systems = More capabilities

In the technology age, agility is key. With FuelCalc, users gain the flexibility they need to plug into and utilize different resources and software systems, which ultimately helps make data management and analysis easier. According to Reinhardt, "An important outcome of this project is the production of computer code that can be linked to other software systems. Someone doing a large scale biomass assessment, greenhouse gas inventory, or risk assessment can take FuelCalc code and link it to their databases with minimal effort."

From statistical analysis and visual representation tools to fire behavior prediction, FuelCalc links to other software systems, including:

- **SVS:** using tree list data and plant form definitions, the SVS creates a graphic representation of a stand which helps depict stand characteristics and structural diversity. User-friendly, the SVS appeals to a variety of audiences and provides the capabilities to design silvicultural treatments as well as generate tabular and graphical summaries of stand information.
- **FOFEM:** fully integrated with FuelCalc, FOFEM predicts tree mortality, fuel consumption, soil heating, and smoke production from prescribed fire and wildfire. FOFEM is also commonly used to produce documentation for NEPA and smoke regulation.
- **NEXUS:** also fully integrated with FuelCalc, NEXUS predicts fire behavior and assesses crown fire hazard. It can compute torching and crowning indices as well as produce fire behavior outputs such as rate of spread, fireline intensity, and reaction intensity.
- **FFE-FVS:** FuelCalc can convert data into files that can be used with FFE-FVS to simulate fuel treatment effects and potential fire behavior over time. Tabular reports are available as well as graphical reports that can be created using the SVS.
- **National Volume Estimator Library:** to estimate the amount of potentially merchantable material generated by simulated thinning treatments, FuelCalc will access the National Volume Estimator Library of equations maintained by the USDA Forest Service Management Service Center.

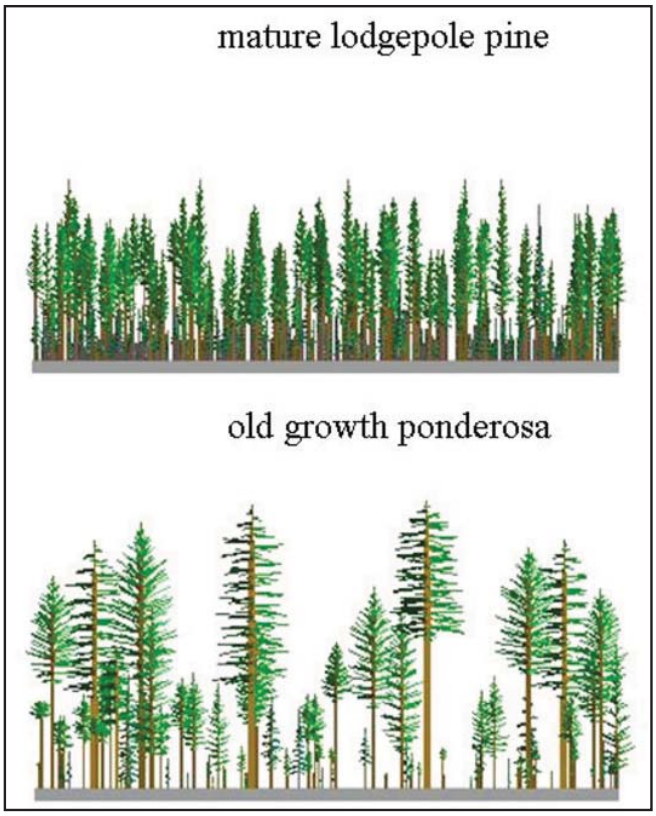


Fire behavior outputs generated by FuelCalc can include type of fire, rate of spread, fireline intensity, flame length, fire intensity scale, and torching index. Credit: screen capture by Joe Scott.

A giant step forward for fuel calculations and more steps to come

Like most software programs, FuelCalc is in a state of ongoing development. User input is welcomed and essential for improvement. As requirements change and funding allows, new functionality and fuel and fire behavior modeling methods may be added to future versions. In addition, to help access the functionality needed to geospatially analyze data, FuelCalc is currently being

considered for inclusion in the ArcFuels geospatial fuel analysis system and the geospatial fuel treatment analysis taught by the National Interagency Fuel Technology Transfer Team.



Examples of two different visual outputs generated by the SVS.

FuelCalc 2.0 is now available upon request through the Missoula Fire Lab Website at http://firelab.fire.org. Additional development work was funded by the National Interagency Fuel Technology Team and managed by Duncan Lutes and the Fire Modeling Institute at the Missoula Fire Sciences Lab.

Further Information: Publications and Web Resources

FFE-FVS: http://www.fs.fed.us/fmsc/fvs/description/ffe-fvs.shtml

Fire Modeling Institute Website (fire systems and tools): http://www.fs.fed.us/fmi/layout%20tools%20table.html

FOFEM: http://www.fire.org/index.php?option=content&task=category&sectionid=2&id=12&Itemid=31

FuelCalc on the Fire Modeling Institute Website: http://www.fs.fed.us/fmi/projects/details/Lutes_Fuel_Calc_detail.html

FuelCalc on the Missoula Fire Lab Website: http://firelab.fire.org

National Volume Estimator Library: http://www.fs.fed.us/fmsc/measure/volume/nvel/index.php

NEXUS: http://www.fire.org/index.php?option=content&task=category&sectionid=2&id=13&Itemid=32

Reinhardt, Elizabeth, Lutes, Duncan, and Scott, Joe. 2006. FuelCalc: A Method for Estimating Fuel Characteristics. USDA Forest Service Proceedings RMRS-P-41. 9 p. Online at: http://www.fs.fed.us/fmi/downloads/reinhardt_fuelcalc.pdf

SVS: http://forsys.cfr.washington.edu/svs.html

Management Implications

FuelCalc:

- Is easy to learn and use.
- Supports a diverse user group, including local and regional fuel management specialists.
- Provides a quantitative method to design fuel treatment alternatives.
- Generates outputs and reports that can be saved, graphed, imported into Microsoft Excel, and exported into a range of other programs.
- Helps fuel managers analyze the potential effects of silvicultural treatments on surface and canopy fuels.
- Encourages greater consistency of inventory data across agencies and applications by making the code available to other software developers (on request).

Scientist Profile

Dr. Elizabeth D. Reinhardt is a Research Forester with the Fire Ecology and Fuels Project at the Rocky Mountain Research Station, Missoula Fire Sciences Laboratory, Missoula, MT. She earned an AB from Harvard University in English and an MS and PhD in Forestry from the University of Montana. Her research has included studies of tree mortality, fuel consumption, modeling fire effects, and canopy fuels. Elizabeth is currently assigned to the Forest Service Policy Analysis staff in Washington DC.

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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JFSP *Fire Science Brief* is published monthly. Our goal is to help managers find and use the best available fire science information.

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