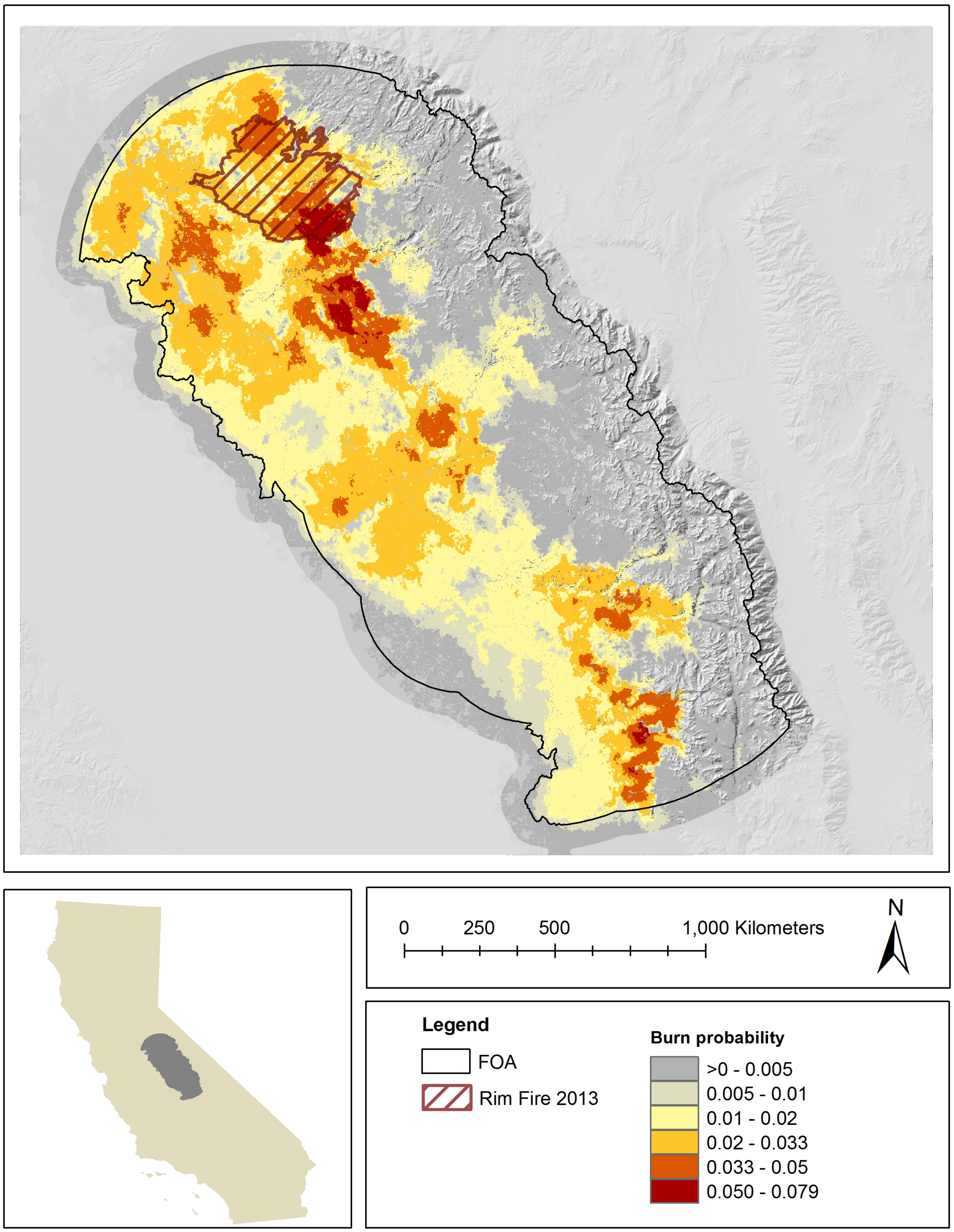
FSim: the large-fire simulator

Guide to best practices



FSim: the large-fire simulator

Guide to best practices

Version 0.3.1

This document is a guide to best practices for using the FSim large-fire simulator, a wildfire occurrence, growth and suppression simulation system produced by Dr. Mark Finney of the Missoula Fire Sciences Lab and Stu Brittain of Alturas Solutions, with the assistance of many USFS research scientists.

This document is not a comprehensive FSim user guide and is not the authoritative documentation for FSim.

FSim is updated episodically, so this document may not be up-to-date with respect to command file switches and versions. Please review all information distributed with the FSim executables for up-to-date information.

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Introduction

1 Introduction

1.1 About FSim

FSim—the large-fire simulation system—is a comprehensive wildfire occurrence, growth and suppression simulation system that estimates wildfire probability and intensity across a large landscape (Finney and others 2011). Because large fires are rare, FSim generates many thousands of years of simulations, in order to capture a long enough time period to generate burn probabilities for the landscape. FSim is a stochastic simulation system that simulates many thousands of iterations, then integrates those iterations into a probabilistic result. An FSim iteration spans one entire year. For that reason, the terms "fire season" and "year" are often used synonymously with iteration. Simulations with FSim typically use ten- to thirty-thousand iterations.

FSim is called the large-fire simulation system because it focuses on the relatively small fraction of wildfires that escape initial attack and become "large". This focus is justified by the historical distribution of fire sizes. Nationwide, the largest 1 percent of wildfires account for between 80 and 99 percent of the area burned, depending on geographic region (Strauss and others 1989). That is, most wildfires are small and contribute very little to total area burned, whereas the relatively few large wildfires account for nearly all of the total area burned.

This is not to say that small wildfires are trivial to fire management in general. Fire management activities—prevention and preparedness in particular—may contribute to this unequal distribution. Successful initial attack, a direct result of preparedness, is a significant factor in keeping most wildfires small. All wildfire ignitions, whether they become large or stay small, are important to consider when planning fire prevention and fire suppression activities. But once we move to the realm of simulating the potential for wildfire effects (such as annual area burned) the disproportionately large amount of area burned by the largest fires suggests an efficiency in focusing on the relatively few large wildfires that burn nearly all of the area.

1.1.1 Simulation process

Several terms used in this section are specifically defined for use in FSim. A single execution of FSim is called a simulation, or simply a 'run'. A simulation consists of many thousands of iterations (up to 100,000). An iteration is the simulation of fire weather, fire occurrence, fire growth, containment and behavior over the course of an entire calendar year. An iteration ends with the last day of the calendar year--Julian day 365. An iteration can result in any number of wildfires, including zero, depending on the fire weather and fire occurrence inputs.

FSim consists of three main wildfire simulation modules (fire occurrence, fire growth and behavior, and fire containment), which are built on the foundation of a fourth module—weather generation. The weather generation module simulates daily values of the Energy Release Component (*ERC*) of the National Fire Danger Rating System (NFDRS; citation). The occurrence module simulates the probability of ignition of a wildfire that eventually grows large, given weather conditions on the day of ignition. This likelihood is calculated as a function of *ERC* for each day of a simulation. The growth module simulates the daily growth of a newly ignited or ongoing wildfire, through both flame front spread and spotting (new fires ignited by embers ahead of the flaming front), as a function of fuel, weather and topography. The suppression, or containment, module simulates the likelihood that, on any given day of a simulation, the modeled wildfire will be contained and therefore no longer grow on subsequent days. The suppression module also includes a perimeter trimming algorithm that simulates progressive containment of a fire perimeter over time. The suppression module therefore shortens the duration of a wildfire and keeps the overall size smaller for a given duration.

As a stochastic simulator, FSim simulates wildfire occurrence, growth and suppression for tens of thousands of iterations, then compiles those results to produce raster datasets which indicate: 1) the annual probability that wildfire will burn each discrete part of the landscape (pixel), and 2) the and probability of burning at each of six flame length classes (and mean fireline intensity) given that it does. FSim also produces the set of simulated fire perimeters (an event set), in ESRI Shapefile format, with certain attributes related to the simulation.

It is important to note that there is no temporal component to FSim beyond a single wildfire season, consisting of up to 365 days. FSim performs independent (and varying) iterations of one year, defined by the fuel, weather, topography and wildfire occurrence inputs provided. FSim does not account for how its simulated wildfires might influence the likelihood or intensity of future wildfires (even within the same simulation year). Each year represents an independent realization of how fires might burn given the current landscape and historical weather conditions from the past few decades.

1.1.1.1 Weather generation

The weather generation module uses time-series modeling to produce simulated daily values of *ERC* based on the trend from 20-30 years of historical data at a representative weather station within the fire modeling landscape. *ERC* is an index of the amount of heat energy available per unit of ground area, which is affected by fuel properties, including fuel moisture, but not by wind speed. Although a set of 20 NFDRS fuel models is available for operational use, the implementation within FSim is explicitly based on the use of NFDRS fuel model G, even if the fuel characteristics would otherwise indicate use of a different NFDRS fuel model in the fire danger rating area. Fuel model G has been shown to relate well to large-fire occurrence (Andrews and others 2003, Riley and others 2012), regardless of the actual fuel conditions in an area. Fuel model G has a significant load in fuel particles greater than 3 inches diameter, so ERC-G is strongly influenced by the moisture content of these long-timelag fuel particles, and is therefore an indicator of long-term fuel dryness. In the remainder of this guide, the term *ERC* can be taken to refer to *ERC-G* unless otherwise noted.

Simulated *ERC* values are sensitive to the seasonal *ERC* trend in the historical daily mean, as well as to variability about the mean and temporal autocorrelation in the daily values (Finney et al 2011). Simulated *ERC* values can therefore exceed the maximum observed during the sample period, so the weather module is not simply 'replaying history' when it produces a year-long simulation of ERC for each iteration. The weather generation module produces a year-long simulation of *ERC* for each iteration. Simulated *ERC* is used in the fire occurrence and fire growth modules.

1.1.1.2 Wildfire occurrence

The fire occurrence module simulates fire ignition as a three-step process. First, the probability of a large-fire day (LFD) is estimated from the simulated *ERC* using a logistic regression equation with coefficients produced from the historical fire occurrence and weather records. In the historical record, an LFD is a day on which at least one large fire was discovered (even if it did not become large until some time later). The user defines what size is a 'large fire' for each analysis; more details on the large-fire threshold are provided later in this guide. For each day of an iteration, FSim generates a random number (between 0 and 1) and compares it to the LFD probability for the day. If the random number is greater than the LFD probability, then no new large fires are established for that day and the simulation proceeds to the next day.

If the random number is less than the LFD probability, then at least one large fire will start, and FSim moves to the second step—determining how many large fires to start. This second step is based on a random draw from the historical distribution of number of large fires per LFD. A single fire starts on most LFDs, but occasionally multiple large fires ignite on the same day.

The third step is to locate the fire(s) on the landscape, which is accomplished by random draw of X-Y landscape coordinates. The random start location is rejected and re-drawn if the random start location falls on an area mapped as nonburnable (bare ground, open water, etc.). Although the start location is randomly selected, the random selection can be influenced by an optional ignition density grid (IDG) that indicates the relative spatial density of large-fire occurrence across the landscape, based on spatial analysis of the historical record. Values in the IDG are assumed to be proportional. FSim scales the IDG values such that the maximum within the landscape is 1 and all other values are relative to that. A location with a scaled IDG value of 0.25 has half of the probability of being selected as an ignition location as one with a value of 0.5. To ensure that the simulated start locations follow the IDG, FSim compares a random number to the scaled IDG value at the preliminary start location. If the random number is higher than the scaled IDG value the location is rejected and a new random X-Y location is drawn. This process repeats until the random number is less than the scaled IDG value.

1.1.1.3 Wildfire growth and behavior

The fire growth module requires significant computation time. Once a fire is ignited, daily fire growth is simulated using the minimum travel time (MTT) fire growth algorithm (Finney 2002). The basic inputs to the fire growth module are a fire modeling landscape (LCP) file, live and dead fuel moisture content values, and wind speed and direction. Another factor affecting wildfire growth is the daily burn period length. In FSim, daily burn period length (hours) is a function of ERC percentile.

Range of ERC-G percentile	Daily burn period length (hours)
80-89	1
90-96	3
97-100	5

The FSim fire growth module accommodates many standard fire behavior modeling options available in other geospatial fire modeling systems, such as a choice of crown fire modeling method, the use of surface fire spread rate adjustment factors, and custom fuel models.

1.1.1.4 Wildfire containment

FSim us unique among fire growth simulation systems in that it simulates the duration of a wildfire (number of burning periods) by simulating the cessation of fire growth. In FSim, fire spread ends for one of several reasons: 1) the fire was stochastically simulated to have been contained by suppression action (an optional feature), 2) the fire encountered a consecutive period of weather conditions during which the fuel was insufficiently dry to sustain fire growth even if dry conditions returned, or 3) the fire burned all contiguous burnable fuel (e.g., an island). In addition to those spread-ending events, all fires terminate spread after Julian Day 365, even if simulated fuel conditions would otherwise support fire growth.

FSim includes an optional wildfire containment module based on a statistical model constructed after examining operational data from large-fire (e.g., ICS-209) reports (Finney and others 2009). The statistical model related the likelihood that a wildfire would be successfully contained on a given day to the length and type of fire growth periods and to the fuel type involved—specifically, whether timber fuel types were involved. Each day was identified as belonging to a high-spread or low-spread period on the fire. Containment is less likely where timber fuel is present, and less likely during high-spread periods. Containment becomes more likely the longer the low-spread period. In timber fuel, the longer the high-spread period the less likely containment becomes, but in other fuel types, containment probability increases with longer high-spread periods. The containment model is implemented stochastically in FSim, where a random number is compared to the containment probability calculated for the day based on the fire's growth history and fuel type at the origin. A successfully contained fire ceases to grow in future days of the season, thereby limiting the size of the fire compared to a no-suppression simulation.

Further, FSim simulates progressive fire perimeter containment using an optional perimeter trimming algorithm, which further reduces fire size. Each day, the perimeter trimming algorithm simulates progressive fireline construction, with the fireline preferentially built in the perimeter segments with lowest fire intensity. Once fireline is built, it restricts the fire's growth and the fire can no longer expand from that segment. The rate at which perimeter trimming occurs can be varied by the user. The suppression/containment module causes the fire to be restricted in the temporal dimension (by determining a date after which the fire no longer expands), and the perimeter trimming algorithm restricts the spatial growth during the period of activity.

1.1.2 Limitations

1.1.2.1 No initial-attack modeling

FSim does not simulate wildfire prevention activities or initial attack success. Instead, FSim assumes that the recent wildfire history on the landscape, which includes the effects of prevention and initial attack success, is a guide to current large-fire occurrence. FSim does not, in its current form, directly simulate the effects of changes in prevention or preparedness on large-fire occurrence and subsequent changes in burn probability.

A fire management unit with many ignitions—justifying significant preparedness funding—may also have low burn probability. In this case, the low burn probability does not necessarily mean that preparedness funding is unjustified. In fact, lower burn probability is, at least in part, a result of preparedness expenditure, which serves to keep more wildfires small. FSim assumes that prevention, preparedness and initial attack success is reflected in the recent historical wildfire occurrence record and continues at that level.

1.1.2.2 Potential for overburn

Although all fires simulated for a particular iteration occur on one computer processor, there is no checking within FSim to ensure that the same pixel is not burned more than once by different fires occurring in the same iteration. Areas burned during an iteration remain available to burn again by another fire, even within the same iteration. Therefore, two or more fires can burn the same pixel during the same iteration; this is called overburn. Overburn can be identified after completion of a simulation by analyzing the fire perimeter shapefile. If the perimeters of fires with the same 'thread' and 'year' value overlap, then overburn has occurred. Overburn can be eliminated from the perimeter data through geospatial processing of the perimeter dataset.

Analysis of a few simulated fire perimeter datasets generated with the suppression module enabled has indicated that overburn is relatively rare and can be ignored for most applications. When using FSim to simulate the frequency and unsuppressed size of all natural ignitions, overburn is potentially quite large--

pixels can burn several times per season. Use caution when using modeled perimeter datasets for analysis of no-suppression scenarios.

1.1.2.3 Underprediction of large-fire occurrence

Before calibration, most FSim simulations will under-predict the annual number of large fires compared to historical occurrence, despite using inputs based on historical large-fire occurrence. There are two known reasons for this under-prediction. First, although FSim is a large-fire simulator and its input coefficients are based on the historical occurrence of large fires, the FSim ignitions are point-source fires; many of them do not become large even if the containment and perimeter-trimming algorithms are not enabled. The fraction of simulated fires that do not reach large-fire status depends on the fire environment as well as the resolution of the fire growth calculations. A review of FSim's tabular results for a simulation will reveal the fraction of fires that do not reach the large-fire size. This fraction varies among simulations, but is commonly in the 20-50% range when containment and perimeter trimming are enabled.

Second, FSim does not start new wildfires if the ERC-G is below the 80th percentile, whereas the fire occurrence coefficients may indicate some probability of that occurring, and fires may historically have started or been discovered on a day when the ERC-G was below the 80th percentile. An analysis of the historical record on XX landscape revealed, however, that very few fires historically started below the 80th percentile ERC-G.

Calibration of large-fire occurrence 85 in FSim alleviates this potential under-prediction.

1.2 Primary datasets

FSim, like all spatial fire growth modeling systems, requires spatial information about fuel, forest vegetation, and topography across the area of interest. This spatial information is called the fire modeling landscape (or sometimes called the fire modeling landscape). The computer file containing the spatial information is called the FARSITE Landscape file (.LCP). In addition to the fire modeling landscape, FSim requires information about historical fire weather (fuel moisture content and wind speed and direction) and historical large-fire occurrence (discovery date, start location, and final fire size) for the most recent 2-3 decades.

1.2.1 Fire modeling landscape (.lcp)

The fire modeling landscape is a set of raster datasets—stored in a "landscape" (.lcp) file—that characterizes surface fuel, canopy fuel (canopy base height, canopy bulk density), forest vegetation (cover and height), and topography (slope steepness, aspect, and elevation) across the required area. More information about the LCP file can be found in the FARSITE and FlamMap help files.

The .lcp file stores rasters representing the fire behavior fuel model (FBFM), canopy base height (*CBH*) and canopy bulk density (*CBD*). The FBFM layer can use any standard fuel model, whether one of the original 13 fuel models (Anderson 1982) or the 40 Scott and Burgan (2005) fuel models. In addition to those standard fuel models, custom fuel models can also be specified in the .lcp. In that case, a custom fuel model file (.fmd) must be generated, and that file must be specified in the FSim command file. See the FARSITE documentation for specific information about the format of the .fmd file.

The .lcp file stores rasters for forest canopy cover and canopy height. FSim uses these rasters to estimate wind reduction factor, which reduces the 20-ft wind speed to the midflame height. FlamMap's fuel moisture conditioning feature also uses the canopy cover raster (to estimate shading of the surface fuelbed); however, this feature is not currently available in FSim.

The .lcp file stores rasters for slope steepness, aspect and elevation. FSim uses slope steepness and aspect to vector wind speed and direction with a slope vector, ultimately producing an effective wind speed and direction. FSim itself does not use the elevation raster, but FlamMap uses elevation for fuel moisture conditioning (a feature not currently available in FSim).

1.2.2 Fuel moisture content (.fw13)

This section is under development.

FSim requires daily historical information about live and dead surface fuel moisture content. RAWS data, in the form of a .fw13 file, typically provide the required information. The .fw13 file is used with FireFamilyPlus to calculate the NFDRS Energy Release Component (ERC), specifically the *ERC* for NFDRS fuel model G *(ERC-G).* In this documentation, *ERC* should be taken to refer to *ERC-G* unless otherwise noted. In its current form, FSim needs historical *ERC* values for one location within the project area.

There are several desired attributes for this historical *ERC* dataset:

1. It should cover the same reference period as the Fire Occurrence Dataset (FOD; generally 1992 to present).
2. It should be for a location within the Fire Occurrence Area (FOA) representative of past large-fire occurrence.
3. It should consist of daily year-round data without missing values. Each year should have 365 *ERC* values (366 in leap years).

Remote Automated Weather Stations (RAWS) are a standard source for *ERC* data. RAWS data can generally satisfy desired attributes 1 and 2 above, but most RAWS-based *ERC* datasets are not year-round throughout the period of record, and may even contain missing values even during the fire season. This presents challenges to correctly parameterizing FSim.

1.2.3 Wind speed and direction (.dat)

This section is under development.

FSim requires hourly information about the distribution of wind speed and wind direction for the project area. FSim uses a separate distribution of speed and direction for each calendar month of the year. RAWS are the primary source of wind data for FSim.

FSim typically works well with the sustained (10-minute average) wind speeds recorded hourly at a RAWS. Only afternoon and evening hours are typically included in the wind speed and direction distributions.

1.2.4 Historical fire occurrence dataset (FOD)

The final dataset needed to set up an FSim run is a Fire Occurrence Database (FOD). For the required fire occurrence area (FOA) extent, the required attributes for the FOD are:

- Start location
- Start (discovery) date

- Final fire size
- Cause class (optional)

The ideal FOD would include all wildfires of any size. At a minimum it should represent all fires that exceed about 100 ha (247 ac). A reasonable middle-ground is a FOD that is reliable for fires greater than about 20 ha (50 ac).

Cause class is optional for most FSim applications. Cause class is required if attempting to use FSim for a specific wildfire cause class, such as natural vs. human caused.

For a FOA with mixed land ownership (which includes almost all possible FOAs), the Short (2015) Fire Occurrence Database is a reliable source of fire occurrence data for parameterizing FSim and setting simulation targets. However, users should read the companion paper by Short (2014) to understand potential limitations of the dataset for their area of interest.

1.3 Ancillary datasets

The ancillary datasets described in this section are not required for setting up or calibrating FSim, but they are extremely useful for those tasks.

1.3.1 Vegetation type

The fire modeling landscape consists of spatial information about surface and canopy fuel across the .lcp extent, but not about the type, cover or height of the vegetation that resulted in those fuel characteristics. When working with LANDFIRE data, there is an inherent relationship between vegetation and fuel because fuel is mapped from vegetation type, cover and height. Keeping LANDFIRE's Existing Vegetation Type (EVT), Existing Vegetation Cover (EVC), Existing Vegetation Height (EVH), and biophysical setting (BpS) data available provides an excellent foundation for critiquing the fuelscape and the FSim results it produces. If edits to the fuelscape are required, it is best to make the edits in the context of vegetation characteristics rather than just fuel.

Likewise, when working with LANDFIRE data, it is very helpful to have the "fuel disturbance" raster available for reference. (LANDFIRE calls this the FDist raster, but do not confuse it with the fire-day distribution file of the same name.) The fuel disturbance raster is an indication of the type, severity and time-since-disturbance of fuel disturbances on the landscape. Fuel disturbances include mechanical fuel treatments, wildfire, insect and disease impacts, and more.

1.3.2 Historical fire perimeters and severity

Although not used for parameterizing FSim, ancillary data on historical large-fire perimeters and severity can prove invaluable during calibration. The Monitoring Trends in Burn Severity (MTBS) project is a good source of both large-fire perimeters and severity data.

1.3.3 Landscape summary units

During calibration, and as part of a simple exposure analysis, it may be useful to summarize FSim results for different summary units--or at least show the boundaries of those units on a map along with the FSim results. Example summary units include:

- Land ownership
- Administrative units (Region/Forest/District, etc.)

- Sub-watersheds (HUC-6)
- Potential Operational Delineations (PODs); see Thompson and others (2016)

1.4 Coordinate system

FSim has three requirements regarding the coordinate system for its spatial inputs. A coordinate system may also known as a "map projection" or "spatial reference".

First, FSim requires the use of a projected coordinate system (PCS); FSim cannot be used with a geographic coordinate system (GCS), which uses latitude and longitude coordinates.

Second, all spatial input data **must be in the same projected coordinate system**. That is, the various spatial inputs must all use the same units of measure (feet or meters), the same datum, and the same projection. Although FSim does not use any projection information that may be carried along with its spatial inputs, it is important to retain that information for each input so that any re-projections can be made, and so that FSim's outputs can be properly assigned a projection. (FSim's outputs will be in the same coordinate system as the LCP file.)

FSim's spatial inputs include:

- .lcp
- ignition density grid
- ignition mask
- barrier file

Third, grid north should be reasonably close to true north across the fire modeling landscape extent. FSim, like all of its related fire growth simulation systems, assumes that grid north is true north. In FSim, a south wind (blowing from south to north) is assumed to blow from the bottom of the raster grid toward the top. The difference between grid north and true north is called the convergence angle. Convergence angle can be calculated for any point in a spatial dataset using using the Calculate Grid Convergence Angle tool in ESRI's ArcMap software. Not all projected coordinate systems produce a north-up grid everywhere within a given area, resulting in potential discrepancy between recorded and simulated wind directions.

An additional consideration for selection of a coordinate system is consistency in the land area represented by a pixel across the area of interest. An equal-area projection is ideal if it does not result in too much deviation between true north and grid north. Typically, the land management unit for which FSim is being used will have a standard projection used for the area. The best practice is to use this local-standard projection as long as it meets the three requirements listed above.

1.5 Units of measure

FSim inputs are in a mix of English and metric units. For example, wind speed is in mi/hr, but canopy fuel characteristics are generally (not not necessarily) in metric units. FSim's outputs are also a mix of English and metric units. For example, the flame-length classes are nominally divided into bins based on flame length measured in feet, but the mean fireline intensity output is in kW/m. The area burned by an individual fire is reported in acres.

Because the units of measure used in FSim are not consistently in English or metric, this guide makes no attempt at consistently using either English or metric units. The mix of units used in this guide is similar to what is used in the practice of spatial wildfire analysis.

For help converting among complex units of measure specific to fire science, we suggest the following sources:

- Google search (e.g. "convert BTU/ft-s to kW/m")
- BehavePlus fire modeling system (Tools | Units converter)
- www.firewords.net (Units Conversion Factors)

FSim command file

2 FSim command file

The FSim command file (.cmdx) is an ASCII text file listing a series of mandatory and optional switches (keywords). The switches can be presented in any order in the command file. For convenience in reviewing and editing the command file, we recommend grouping the switches into three types:

- input filenames
- simulation settings
- output filenames

The general switch format is as follows:

```
<Switch>: <Value>
```

Note the colon and the minimum of 1 space of whitespace after the colon and before the value. The whitespace can be one or more blanks (spaces) and/or tabs. A switch must start in the first column, and the switch and corresponding value must appear on the same line. A '#' in the first column indicates a comment line.

Note that FSim is extremely sensitive to the syntax of each switch. If there is a hard-to-notice typo in a switch, FSim will not recognize it and will continue as if the switch were not present in the .cmdx file, continuing with the default value if the switch is not mandatory. For example, this switch in the command file

```
JulainStart: 170
```

has a typographical error and will not be recognized by FSim. FSim will proceed as if the correct switch were not present; it will not start all simulated fire seasons on Julian Day 170 (June 19). Instead, FSim will start all simulations at the default of Julian Day 30. The only way to know that the switch is not being recognized is to carefully review the results and notice that fires are starting before Julian Day 170.

There is no error message or log file, so the user must take steps to verify correct switch operation.

2.1 Input filenames

Many FSim command file switches refer to an input filename. The switch is followed by an optional path and then the filename. If no path is specified, the input file is expected to be in the folder from which FSim was executed, which, following these best-practices, is the folder containing the .cmdx file. It is quite messy to keep FSim's input files in the same folder as the .cmdx file, because those inputs will likely be used for successive calibration runs, each with its own run folder. We recommend that the inputs for a particular FOA be kept in a separate folder, and specify the path to that folder in the command file.

For example, all input files for the Lake Tahoe Basin Management Unit (LTBMU) project could be kept in a folder called '_inputs':

```
landscape:      Z:\Projects\LTBMU\fsim\_inputs\LTBMUv1.lcp
```

We use an underscore at the beginning of the inputs folder so that it will be listed at the top of the list of folder contents. We recommend appending a version number to every FSim input, beginning with v1 for the initial version of each input.

The table below lists the required and optional input files. These inputs are specified in the command file; the command file is specified at run time. The table below uses a recommended file-naming convention, but others are possible. See the file-naming convention topic for more details.

Switch	Input file	Recommended file extension	Required?
landscape:	Landscape file	.lcp	Yes
FriskFile:	Fire Risk Export file	.frisk	Yes
FireDayDistributionFile:	Fire-day distribution file	.fdist	Yes
ROSAdjust:	Rate of spread adjustment factor file	.adj	
ErcStreamFile:	ERC stream	.erc	
FMS80:	FMS file for 80th percentile ERC	_80.fms	
FMS90:	FMS file for 90th percentile ERC	_90.fms	
FMS97:	FMS file for 97th percentile ERC	_97.fms	
IgnitionProbabilityGrid:	Ignition density grid	_idg.asc	
IgnitionMask:	Ignition Mask	_mask.asc	
BarrierFile:	Barrier file	_barrier.shp	

2.2 Simulation settings

The table below lists options for the simulation settings specified in the command file.

Setting	Required?	Default	Options
Resolution:	yes		Floating point or integer
NumSimulations:	yes		Integer (
GridDistanceUnits:			0 = meters; 1 = feet
Record:		0	0 = use previously recorded ERC (replay); 1 = record new ERC
JulianStart:		30	Integer from 1 to 365
Suppression:		0	0 = suppression off; 1 = suppression on
SuppressionFactor:		0	floating point; <= 0 = trimming off
NoSuppressionNonBurnDaysLimit:		21	Integer
CrownFireMethod:		0	0 = Finney; 1 = Scott and Reinhardt
FireSizeLimit:		-1	Integer or floating point; '-1' for unlimited
ThreadsPerFire:		1	Integer from 1 to 64
FireListOnly:		0	0 = no; 1 = yes
OutputFirePerims:		0	0 = no; 1 = yes
EmberOutputs:		3	0 = none; 1 = CSV; 2 = shapefile; 3 = CSV and shapefile
GenerateGriddedWinds:		0	0 = no; 1 = yes
GriddedWindsResolution:		?	Unsure of the default, if any
OutputGriddedWinds:		0	0 = no; 1 = yes
BurnCellsOnlyOnce:		0	0 = no; 1 = yes

2.3 Output filenames

There are only two output filenames to specify in the command file. The first is the root name to use for all other FSim outputs. The second is an optional progress text file that indicates the simulation progress as a fraction.

Switch	Output	extension	Required?
OutputsName:	Outputs rootname	none	Yes
ProgressFilePathname:	FSim progress text file	.txt	

2.4 Complete CMDX file

Below is a sample FSim command file listing all current switches available in FSim. The example is for a project for the Lake Tahoe Basin Management Unit (LTBMU). In the example, the LTBMU fsim analysis is stored in a folder on the Z: drive: (`Z:\Projects\LTBMU\fsim\`).

More detail on each switch can be found in following sections. Information about the file-naming convention used in this example can be found here[34].

```
landscape:                      Z:\Projects\LTBMU\fsim\_inputs\lcp\LTBMUv1_180m.lcp
FriskFile:                      Z:\Projects\LTBMU\fsim\_inputs\frisk\LTBMUv1.frisk
FireDayDistributionFile:        Z:\Projects\LTBMU\fsim\_inputs\fdist\LTBMUv1.fdist
FMS97:                          Z:\Projects\LTBMU\fsim\_inputs\fms\LTBMUv1_97.fms
FMS90:                          Z:\Projects\LTBMU\fsim\_inputs\fms\LTBMUv1_90.fms
FMS80:                          Z:\Projects\LTBMU\fsim\_inputs\fms\LTBMUv1_80.fms
IgnitionProbabilityGrid:        Z:\Projects\LTBMU\fsim\_inputs\idg\LTBMUv1_idg.asc
IgnitionMask:                   Z:\Projects\LTBMU\fsim\_inputs\mask\LTBMUv1_mask.asc
ROSAdjust:                      Z:\Projects\LTBMU\fsim\_inputs\adj\LTBMUv1.adj
customfmd:                      Z:\Projects\LTBMU\fsim\_inputs\fmd\LTBMUv1.fmd
BarrierFile:                    Z:\Projects\LTBMU\fsim\_inputs\barrier\LTBMUv1_barrier.shp
ErcStreamFile:                  Z:\Projects\LTBMU\fsim\_inputs\erc\LTBMUv1.erc
Record:                         1
Resolution:                     270
NumSimulations:                 10000
JulianStart:                    30
CrownFireMethod:                1
FireSizeLimit:                  -1
Suppression:                    1
SuppressionFactor:              2.5
NoSuppressionNonBurnDaysLimit:  21
FireListOnly:                   0
ThreadsPerFire:                 1
GridDistanceUnits:              0
OutputFirePerims:               1
EmberOutputs:                   1
GenerateGriddedWinds:           1
GriddedWindsResolution:         270
OutputGriddedWinds:             1
BurnCellsOnlyOnce:              0
OutputsName:                    LTBMUr1
ProgressFilePathname:           LTBMUr1_progress.txt
```

2.5 Command file switches

The following sections contain detailed information about the use of each FSim command file switch.

2.5.1 landscape

Switch type: Mandatory. If this switch is not present or the specified file is not valid, FSim will fail to run.

Switch format: landscape: <value>

Example usage: landscape: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1_180m.lcp

Discussion: Specifies the .lcp file to use for the simulation.

Landscape files occasionally require edits as changes are needed. For that reason we suggest always appending a version number to the .lcp filename. The underlying fire modeling landscape data are usually kept at their native resolution, then resampled to a different (usually coarser) resolution to correspond to the resolution of a particular FSim run. The .lcp resolution can be determined by opening the .lcp file in FARSITE, FlamMap or even ArcMap, but we nonetheless recommend appending the .lcp cell resolution to the filename as in the example above. See the FARSITE landscape file[37] topic for more details.

2.5.2 FriskFile

Switch type: Mandatory. If this switch is not present or the specified file is not valid, FSim will fail to run.

Switch format: FriskFile: <value>

Example usage: FriskFile: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1.frisk

Discussion: Specifies the .frisk file to use for the simulation.

The .frisk file contains detailed information about the annual trend in ERC (mean and standard deviation), percentile values of ERC and dead fuel moisture content, and historical wind speed and direction. It is generated by FireFamilyPlus. See the Frisk file[40] topic for details.

2.5.3 FireDayDistributionFile

Switch type: Mandatory. If this switch is not present or the specified file is not valid, FSim will fail to run.

Switch format: FireDayDistribution: <value>

Example usage: FireDayDistribution: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1.fdist

Discussion: Specifies the .fdist file to use for the simulation.

The .fdist file contains three important pieces of information for FSim: logistic regression coefficients for the probability of a large-fire day in relation to ERC, Acrefract (the ratio of fire simulation area to fire occurrence area), and the distribution of the number of large fires per large-fire day. See the FDist file[43] topic for details.

2.5.4 FMS97

Switch type: Optional. If this switch is not present or the specified file is not valid, FSim will read fuel moisture values to use for the 97th percentile ERC bin from the .frisk file.

Switch format: FMS97: <value>

Example usage: FMS97: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1_97.fms

Discussion: Specifies the .fms file to use for the 97th percentile ERC bin.

A value of -1 for this switch indicates that no .fms file is specified. See the discussion of .fms files here[45].

2.5.5 FMS90

Switch type: Optional. If this switch is not present or the specified file is not valid, FSim will read fuel moisture values to use for the 90th percentile ERC bin from the .frisk file.

Switch format: FMS90: <value>

Example usage: FMS90: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1_90.fms

Discussion: Specifies the landscape file to use for the 90th percentile ERC bin.

A value of -1 for this switch indicates that no .fms file is specified. See the discussion of .fms files here[45].

2.5.6 FMS80

Switch type: Optional. If this switch is not present or the specified file is not valid, FSim will read fuel moisture values to use for the 80th percentile ERC bin from the .frisk file.

Switch format: FMS80: <value>

Example usage: FMS80: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1_80.fms

Discussion: Specifies the landscape file to use for the 80th percentile ERC bin.

A value of -1 for this switch indicates that no .fms file is specified. See the discussion of .fms files here[45].

2.5.7 ROSAdjust

Switch type: Optional. If this switch is not present or the specified file is not valid, FSim will not adjust spread rates (equivalent to adj values of 1.0 for all fuel models).

Switch format: ROSAdjust: <value>

Example usage: ROSAdjust: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1.adj

Discussion: Specifies the rate of spread adjustment factor file to use for the simulation.

A value of -1 for this switch indicates that no rate-of-spread adjustment factor file is specified. That is equivalent to an adjustment factor of 1.0 for all fuel models. See the Rate of Spread Adjustment factor[49] topic for details.

2.5.8 IgnitionProbabilityGrid

Switch type: Optional. If this switch is not present or the specified file is not valid, FSim will uniformly distribute fire start locations across the landscape.

Switch format: IgnitionProbabilityGrid: <value>

Example usage: IgnitionProbabilityGrid: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1_idg.asc

Discussion: Specifies the ignition density grid file to use for the simulation.

A value of -1 for this switch indicates that no ignition probability grid is specified. See the Ignition Density Grid [47] topic for details.

2.5.9 ErcStreamFile

Switch type: Optional. If this switch is not present or the specified file is not valid, FSim will generate ERC streams based on the 'Time Series Data' section of the .frisk file.

Switch format: ERCStreamFile: <value>

Example usage: ERCStreamFile: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1.erc

Discussion: Specifies the ERC Stream file to use for the simulation.

A value of -1 for this switch indicates that no .erc stream file is specified. In that case FSim will generate ERC streams based on the information in the Time Series Data section of the .frisk file. See the ERC stream file [51] topic for details.

2.5.10 IgnitionMask

Switch type: Optional. If this switch is not present or the specified file is not valid, FSim will not mask out any ignitions. The ignition mask feature of FSim has not been well tested; use caution and verify the feature is working correctly before relying on simulation results.

Switch format: IgnitionMask: <value>

Example usage: IgnitionMask: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1_mask.asc

Discussion: Specifies the Ignition Mask file to use for the simulation.

A value of -1 for this switch indicates that no ignition mask is specified. See the Ignition Mask [51] topic for details.

2.5.11 customfmd

Switch type: Optional. If this switch is not present or the specified file is not valid, FSim will not use custom fuel models specified in the LCP. The custom fuel model feature of FSim has not been well tested; use caution and verify the feature is working correctly before relying on simulation results.

Switch format: customfmd: <value>

Example usage: customfmd: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1.fmd

Discussion: Specifies the custom fuel model file to use for the simulation.

A value of -1 for this switch indicates that no custom fuel model file is specified. See the Custom Fuel Model file[49] topic for details.

2.5.12 BarrierFile

Switch type: Optional. If this switch is not present or the specified file is not valid, FSim will not correctly use the barrier file. The barrier file feature of FSim has not been well tested; use caution and verify the feature is working correctly before relying on simulation results.

Switch format: BarrierFile: <value>

Example usage: BarrierFile: Z:\Projects\LTBMU\fsim_inputs\LTBMUv1_barrier.shp

Discussion: Specifies the Barrier file to use for the simulation.

A value of -1 for this switch indicates that no barrier shapefile is specified. See the Barrier File[51] topic for details.

2.5.13 BurnCellsOnlyOnce

Switch type: Optional. The default is false (0).

Switch format: BurnCellsOnlyOnce: <value>

Example usage: BurnCellsOnlyOnce: 0

Discussion: Sets limitation of a cell burning only once per entire simulation.

The BurnCellsOnlyOnce <value> can be 0 (false) or 1 (true).

2.5.14 GridDistanceUnits

Switch type: Mandatory.

Switch format: GridDistanceUnits: <value>

Example usage: GridDistanceUnits: 0

Discussion: Sets the distance units used in the spatial inputs--meters or feet.

The GridDistanceUnits switch should be set to whatever units are used in the LCP. Typically, that is meters. The GridDistanceUnits <value> can be 0 (meters) or 1 (feet). The Resolution[31] switch must be in the same grid-distance units. FSim runs to completion without this switch present in the command file,but it is unclear what value FSim uses as the default in that case.

2.5.15 ThreadsPerFire

Switch type: Optional. The default is 1.

Switch format: `ThreadsPerFire: <value>`

Example usage: `ThreadsPerFire: 1`

Discussion: Sets the number of processing threads per fire.

The ThreadsPerFire <value> can be an integer from 1 to 64. We always use the default of 1.

2.5.16 OutputFirePerims

Switch type: Optional. The default is false (0).

Switch format: `OutputFirePerims: <value>`

Example usage: `OutputFirePerims: 1`

Discussion: Sets whether to output fire perimeters (polygons) for the simulation.

According to the documentation, any switch value greater than or equal to 1 will set the switch to true; any value less than 1 will set the switch to false. For clarity, we suggest using OutputFirePerims <value> 0 (false) and 1 (true). We suggest always setting this switch to TRUE because the downside of wishing you had perimeters when you didn't generate them is much greater than the downside of making but not needing them.

2.5.17 FireListOnly

Switch type: Optional. The default is false (0).

Switch format: `FireListOnly: <value>`

Example usage: `FireListOnly: 0`

Discussion: Sets whether to simulate only weather, occurrence and containment.

Setting this switch to true causes FSim to simulate weather, occurrence and containment, but not fire growth or perimeter trimming. This option can be used to check the ERC simulation, FRISK, FDist and IDG without the need to wait through the fire growth calculations. The FireListOnly <value> can be 0 (false) or 1 (true).

2.5.18 FireSizeLimit

Switch type: Optional. The default is unlimited fire size.

Switch format: `FireSizeLimit: <value>`

Example usage: `FireSizeLimit: -1`

`FireSizeLimit: 500000`

Discussion: Sets the upper limit on the size of a simulated fire.

A switch value of -1 indicates to grow fires without a size limit. A fire exceeding the size limit is removed entirely from the simulation and not replaced with another fire, which, in any event, would grow under the same wind/moisture conditions as the one that exceeded the size threshold. The addition of the SuppressionFactor [30] switch has essentially obviated the need for this switch. The FireSizeLimit <value> can be floating point or integer.

2.5.19 JulianStart

Switch type: Optional. The default <value> is 30.

Switch format: `JulianStart: <value>`

Example usage: `JulianStart: 1`

Discussion: Sets the Julian date on which to start the fire occurrence simulations.

The JulianStart <value> can be an integer greater than 0 and less than 365. Its purpose is to let FSim skip the fire occurrence module if there are typically no large-fire starts until later in the year. The best practice is to let FSim simulate fire occurrence starting with January 1. If early-year ERCs are low (below the year-round 80th percentile), then FSim won't start fires early in the season even if the JulianStart is set to 1. In that case, setting this switch to a value near when large fires actually do occur will not save any simulation time, because the ERC simulation always begins at Julian Day 1.

Do not use a <value> of -1 as a signal to use the default of Julian day 30; this does bad things to the simulation.

2.5.20 Record

Switch type: Optional. The default is 0 (false), which is to replay a previously recorded simulation.

Switch format: `Record: <value>`

Example usage: `Record: 1`

Discussion: Sets whether to replay or freshly record a random sequence of weather and fire occurrence.

The Record <value> can be 1 (true; record new random sequence of weather and fire-occurrence) or 0 (false; replay previously recorded weather and fire-occurrence sequence). Typically, Record is set to 1 for most simulations. Subsequently setting Record to 0 will cause FSim to use the same fire start dates, locations and durations, with the same ERCs and winds. However, other factors that affect fire growth can be changed, including the landscape, FMS, ROSAdjust, and Barrier files, as well settings such as the CrownFireMethod, suppression factor, and resolution.

2.5.21 NoSuppressionNonBurnDaysLimit

Switch type: Optional. The default value is 21 days

Switch format: `NoSuppressionNonBurnDaysLimit: <value>`

Example usage: `NoSuppressionNonBurnDaysLimit: 7`

Discussion: Sets an upper limit on the number of consecutive nonburn days in a no-suppression simulation.

This switch applies only to simulations for which the Suppression Module is not used (Suppression: 0); it is ignored if the Suppression Module is enabled (Suppression: 1). This switch sets the maximum allowable number of consecutive nonburn days (days below the 80th percentile ERC) before a fire is assumed to self-extinguish. Without such a limit, a fire in a no-suppression simulation could lay dormant but still able to become active, if ERC rises above the 80th percentile) even after months of consecutive nonburn days. The default value of 21 days means that a fire is terminated after 21 consecutive days with ERC below the 80th percentile. The NoSuppressionNonBurnDaysLimit <value> can be an integer. Also see the Suppression [29] switch topic.

2.5.22 Suppression

Switch type: Optional. The default value is 0 (no suppression).

Switch format: `Suppression: <value>`

Example usage: `Suppression: 1`

Discussion: Sets whether to use the suppression (containment) algorithm for a simulation.

The suppression algorithm uses a stochastic model of wildfire containment that can shorten the duration of a simulated wildfire. The Suppression <value> can be 0 = false (no suppression) or 1 = true (enable suppression algorithm).

WARNING: do not use a <value> of -1 to disable the suppression module. A switch value of -1 enables the suppression module.

If the Suppression Algorithm is enabled (Suppression: 1), there are a number of ways that a fire's growth is terminated:

1. A limit on the number of consecutive days with ERC below the 80th percentile is reached. This limit is 7 days for a fire starting in a timbered fuel model (fuel model numbers 8-13 and 161 and greater) and 2 days if the fire started in a pixel with a non-timber fuel model (all other fuel model numbers).
2. Containment is determined by a probabilistic algorithm based on the fire's duration and whether it is experiencing a period of high or low growth. There are two such containment models, one for timbered fuels and the other for non-timbered. The determination of timber/nontimber is as identified in item 1 above.
3. All parts of a fire perimeter have reached nonburnable land (a fire on an island, for example).
4. Julian Day 365 was reached. Regardless of weather conditions, simulated fires do now grow into the new year.

If the Suppression Algorithm is not enabled (Suppression: 0), there are three ways that a fire's growth is terminated:

1. The limit on the number of consecutive days with ERC below the 80th percentile is reached (limit is set with the NoSuppressionNonBurnDaysLimit [28] switch)
2. All parts of a fire perimeter have reached nonburnable land (a fire on an island, for example).

3. Julian Day 365 was reached. Regardless of weather conditions, simulated fires do now grow into the new year.

2.5.23 SuppressionFactor

Switch type: Optional. The default is 0.0 (no perimeter trimming)

Switch format: `SuppressionFactor: <value>`

Example usage: `SuppressionFactor: 2.5`

Discussion: Sets the alpha parameter on the perimeter trimming function.

WARNING: setting suppression factor to a positive number automatically turns on the suppression algorithm even if the Suppression: switch is set to 0. So, to fully disable suppression you must either omit the SuppressionFactor switch or set it to zero in addition to setting Suppression: 0.

The alpha parameter controls the rate at which the perimeter is trimmed (analogous to the rate at which fireline is constructed). The SuppressionFactor <value> can be a floating point value greater than or equal to 0.

2.5.24 CrownFireMethod

Switch type: Optional. The default value is 0 (Finney 1998 crown fire method)

Switch format: `CrownFireMethod: <value>`

Example usage: `CrownFireMethod: 1`

Discussion: Sets the crown fire modeling method to use for the simulation.

Omitting the switch will cause FSim to default to the Finney (1998) crown fire method. CrownFireMethod <value> can be 0 = Finney (1998) or 1 = Scott and Reinhardt (2001). Setting CrownFireMethod: 1 tends to produce reasonable results with most sources of fire modeling landscape data.

2.5.25 NumSimulations

Switch type: Mandatory. There is no default value.

Switch format: `NumSimulations: <value>`

Example usage: `NumSimulations: 10000`

Discussion: Sets the number of iterations (years) to simulate during a simulation.

The actual number of iterations depends on the number of processing threads used in the simulation. The actual number if iterations is calculated as RoundUp(NumSimulations/threads)*threads. For example, on a machine running 32 threads and

```
NumSimulations: 10000
```

the actual number of iterations is 10000/32 = 312.5. That rounds up to 313, and 313 * 32 = 10,016 iterations. That same nominal number of iterations on a 48-thread machine would produce 10,032 iterations.

The NumSimulations <value> can be any positive integer.

Technically, NumSimulations is optional. If this switch is not present, FSim does one simulation per available thread.

2.5.26 EmberOutputs

Switch type: Optional. The default value is 3 (output both CSV and Shapefile formats).

Switch format: `EmberOutputs: <value>`

Example usage: `EmberOutputs: 3`

Discussion: Sets whether to generate outputs related to ember launch and land locations.

Ember outputs are a new and yet-untested feature of FSim that generates a CSV and/or point Shapefile with information about the launch and land locations of embers lofted by all fires in a simulation. The launch location is the cell center of the cell that generated the ember. The landing location is the cell center nearest to where the ember lands. The Shapefile identifies the landing location natively, but the attribute table includes information about the launch location. Ember-travel distance can be calculated from the launch and land coordinates. Many embers launch and land at the same locations, so it is necessary to process the point results: a simple count of embers landed at a given cell center or generate a smoothed point- or kernel-density raster.

The EmberOutputs <value> can be:

0 = no ember output
1 = ember output in CSV format
2 = ember output in ESRI Shapefile format
3 = ember output in both CSV and Shapefile formats

2.5.27 Resolution

Switch type: Mandatory.

Switch format: `Resolution: <value>`

Example usage: `Resolution: 270`

Discussion: Sets the resolution of the fire growth calculations in a simulation.

The resolution switch sets the resolution of the fire growth calculations. The units must be the same as the LCP file, and are specified with the required GridDistanceUnits[26] switch. The resolution can be any value, without regard to the cell size in the LCP. FSim resamples the LCP to the specified resolution. However, it is a good practice to set the resolution equal to the LCP cell size (or, conversely, to use an LCP cell size equal to the desired resolution) so that the fuel and vegetation characteristics can be known for each FSim pixel.

Resolution <value> can be any floating point or integer value.

Although you should always include a Resolution switch, if this switch is omitted FSim will use some default resolution. In one test run on a 60-m resolution LCP, FSim used a 30 m resolution when this switch was omitted.

2.5.28 ProgressFilePathname

Switch type: Optional. If this switch is not present, FSim will not generate a progress text file.

Switch format: `ProgressFilePathname: <value>`

Example usage: `ProgressFilePathname: LTBMUr1_progress.txt`

Discussion: Sets the path and filename for an optional simulation-progress text file.

The ProgressFilePathname switch enables the generation of a continuously updated text file that shows the progress of a simulation. During the early part of a simulation (e.g. when FlamMap is running) the file contains text saying "Initializing...". During the risk calculations, the file shows the fraction of iterations for which simulation has started (not finished). After the simulation is completed the file will still read "1.0000 started", meaning that 100 percent of the iterations were started. Because some iterations can take a very long time to complete, the file may read "1.0000 started" long before the simulation finally finishes.

2.5.29 OutputsName

Switch type: Mandatory. There is no default value. If this switch is not present or the specified file is not valid, FSim will fail to run.

Switch format: `OutputsName: <value>`

Example usage: `OutputsName: LTBMUr1`

Discussion: Sets the root filename for outputs generated by the simulation.

FSim generates several final outputs for each run. The OutputsName setting identifies the root filename to use for these outputs. It appends the type of output to this root name, along with an appropriate file extension. For example, if the OutputsName switch specifies `LTBMUr1`, the burn probability raster would be `LTBMUr1_BurnProb.asc`.

If outputs with the same path and root name already exist, they will be overwritten without warning. If no path is specified, the outputs are written to the run folder, otherwise the outputs are written to the specified path. Typically, we do not specify a path, so the outputs are written to the run folder, which is where the .cmdx file is also stored.

FSim input files

3 FSim input files

Except for its spatial inputs, all FSim inputs are ASCII text and can be edited in any text editor. We recommend the free open-source Notepad++ or similar feature-rich text editor. Some of those inputs files can be edited in Excel, then copied and pasted into Notepad++ (the .adj and .fms files, for example).

3.1 File-naming conventions

FSim does not require any particular naming convention—any input file can be given any filename or file extension as long as it is correctly referenced in the command file (which itself can have any name or extension). Nonetheless, it is good practice to use filenames that follow a few simple rules.

First, in each filename, include reference to the project and, optionally, to the FOA within the project, if there is more than one. Second, always include a version number for every input file, starting with v1. As you go through the FSim calibration process, you may need to make a change to any of the input files. Without a version number to update, it is tempting to simply overwrite the current file, which wipes out any documentation of what the initial file content was. For example, the initial .frisk file for FOA 1 of the Lake Tahoe Basin Management Unit project could be `LTBMUv1.frisk`. If an edit needs to be made for a subsequent run, simply increment the version number. Several commonly used methods are described below.

Prefix method

Append the type of file to the beginning of the filename. This method keeps similar input file types together when sorted, and the contents are known without opening the file. The extension is .txt, so the file opens with the default text editor for the machine.

```
frisk_LTBMU_v1.txt
```

Suffix method

With the suffix method, insert the type of file after the project name. This approach allows you to keep all files associated with a run together by using a common root name. It is not unlike how FSim appends the type of output file to the root output name.

```
LTBMU_frisk_v1.txt
```

File-extension method

Use a file extension unique to the input file, even if it is a simple text file. You can then use Windows Explorer filters to focus on a certain input file. Using this method you must set the default program to a text editor. This is the approach used with FARSITE, so it is the approach we will use in this guide.

```
LTBMU_v1.frisk
```

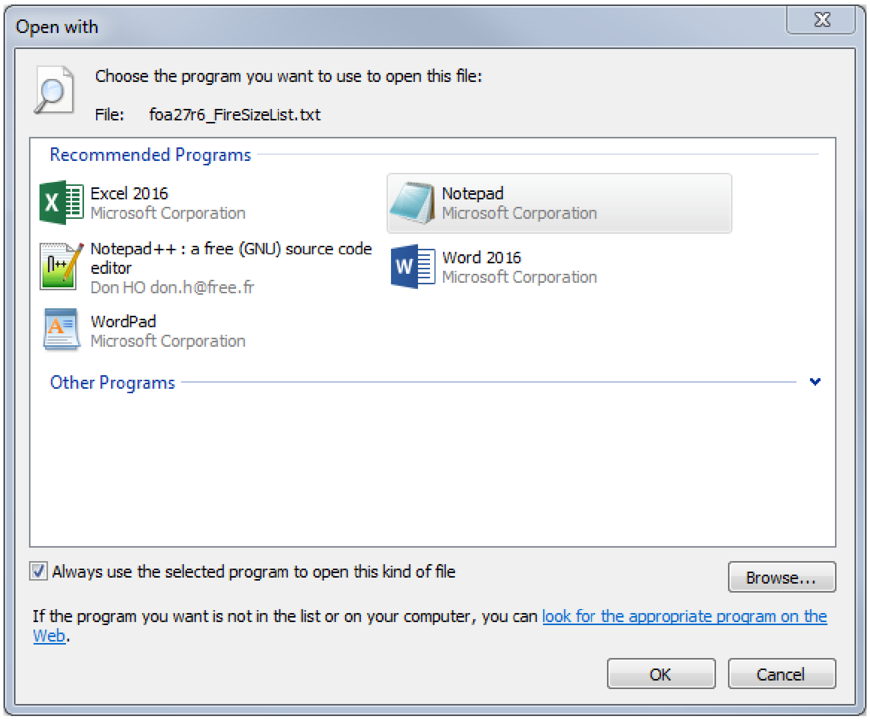
3.2 Standard file extensions

There is no mandatory file-extension standard when using FSim; you may use almost any fire-naming convention you wish. However, we suggest the following mix of suffix and file-extension methods for each input.

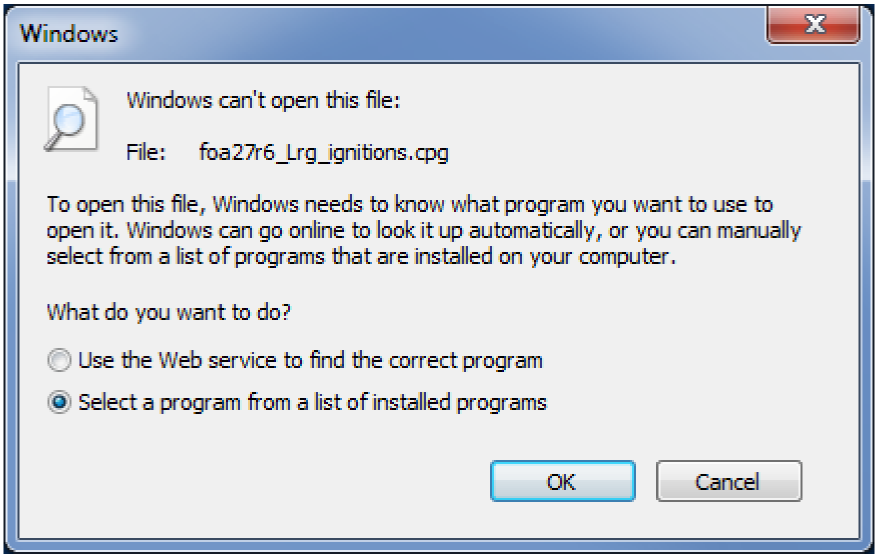
File type	Convention	Reason
landscape file	[PRJ]v[version]_[resolution].lcp example: LTBMUv1_180m.lcp	The .lcp extension is the *FARSITE* standard for the binary LCP file.
Ignition density grid	[PRJ]v[version]_idg.asc example: LTBMUv1_idg.asc	The .asc extension is an ArcGIS standard for an ASCII raster. The '_idg' appended to the filename, before the extension, indicates the file is the Ignition Density Grid.
Fire Risk export file	[PRJ]v[version].frisk example: LTBMUv1.frisk	The .frisk file is a text file, but we suggest using the .frisk extension and setting a file association to open .frisk files with a text editor.
Fuel moisture files	[PRJ]v[version]_[ERC bin].fms examples: LTBMUv1_80.fms LTBMUv1_90.fms LTBMUv1_97.fms	The .fms extension is the *FARSITE* standard for the fuel moisture file. This file can be edited in *FARSITE* or any text editor. FSim can use up to three .fms files for a given run. These correspond to the 80th, 90th and 97th percentile values.
Fire-day distribution	[PRJ]v[version].fdist example: LTBMUv1.fdist	The .fdist file is a text file, but we suggest using the .fdist extension and setting a file association to open .fdist files with a text editor.
Rate of spread adjustment factor file	[PRJ]v[version].adj example: LTBMUv1.adj	The .adj extension is the *FARSITE* standard for the rate of spread adjustment factor file. This file can be edited in *FARSITE* or any text editor.
Ignition mask	[PRJ]v[version]_mask.asc example: LTBMUv1_mask.asc	The .asc extension is an ArcGIS standard for an ASCII raster. The '_mask' appended to the filename before the extension indicates the file is the Ignition Mask.
FSim command file	[PRJ]r[run].cmdx example: LTBMUr1.cmdx	The command files is a text file, so the extension .txt can be used, however, we recommend .cmdx.
Progress text file	[PRJ]r[run]_progress.txt example: LTBMUr1_progress.txt	We opted to leave the file extension for this optional output file as .txt so that its contents can be viewed in the preview pane of Windows Explorer.
Version text file	[PRJ]r[run].version example: LTBMUr1.version	This is a text file optionally generated during batch file execution of FSim. Its purpose is to document what version of FSim was used for a particular run.
FSim outputs	[PRJ]r[run] example: LTBMUr1	We use the same project-and-run naming convention for FSim outputs. FSim uses the suffix method to append the type of output to the specified root name. For example: LTBMUr1_BurnProb

3.3 Windows file associations

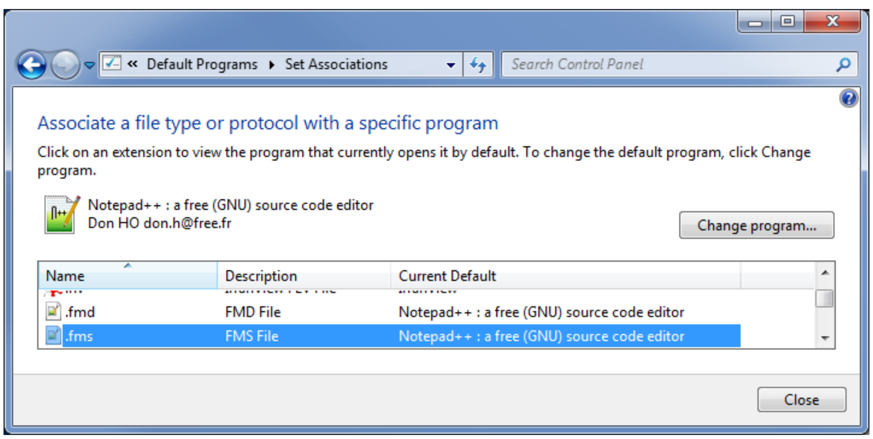
When using the file-extension method of naming FSim input files, it is convenient to set the Windows default program for opening certain file types (file association). In the Windows file explorer, navigate to any file with the extension for which you want to set the file association. Right-click on the file and, if available, choose 'Open with', then choose 'Choose default program...". If the desired program is not listed with the recommended programs, click the Browse... button and navigate to where the program's executable file is located. You may need to first locate the folder where the program's executable file is found.



If there is no 'Open with' option, then there is no file association yet. In that case, choose 'Open' then select a program from a list of installed programs. It may be necessary to first locate, using Windows Explorer, the installation folder for the program you wish to associate.



You can also review the whole list of file associations on your machine at once in the Windows with the Set Associations dialog. Click the Start icon or key, then search for 'associate', and choose 'Change the file type associated with a file extension'. That brings up the dialog box shown below (for Windows 7). Select the file extension you want to change (the .fms file, for example), and then click the 'Change program...' button. Select the application from the list of options, or navigate to the application's executable file.



3.4 Input files

In this section we describe the required and optional FSim input files, and options for generating them. Any input-file details refer to inputs for the example FSim project presented in the Setting up FSim 62 section. The example is for the Lake Tahoe Basin Management Unit, California and Nevada.

3.4.1 .lcp--FARSITE landscape file

The landscape file (.lcp) is a required input for running FSim. It is a custom binary multi-band raster file format that can be generated using several software tools. For use in FSim the .lcp file should contain the following fuel, vegetation and topography rasters:

- surface fire behavior fuel model (FBFM)

- forest canopy cover (CC)
- forest canopy height (CH)
- forest canopy base height (CBH)
- forest canopy bulk density (CBD)
- slope steepness
- aspect
- elevation

The CH, CBH and CBD rasters are technically optional (FSim will operate without them), but their inclusion is critical to correctly simulating fire growth across the landscape. The .lcp file format can also include rasters representing duff loading and coarse woody fuel (larger than 3 inches diameter). Those rasters support functions that are not utilized by FSim, so they do not need to be present.

In order to generate an .lcp file these rasters must:

- be in the same coordinate system
- have the same grid-cell size
- be co-registered
- have the same extent (number of rows and columns)

For more information on the .lcp file format and the nature of the rasters it contains, please see the FARSITE and FlamMap help files, and the Fuel section of the LANDFIRE project website.

Discussion

Like all spatial data, the data in the .lcp file are in a known coordinate system (also called the spatial reference). For use in FSim and other fire growth modeling systems, there are some limitations and guidelines for that coordinate system17 .

A best practice when using FSim is to generate the LCP at the same cell size as the resolution specified in the command file. This is not a strict requirement--FSim will resample the LCP to the desired simulation resolution at run time--but it is a suggested practice so that the fuel profile for each output cell can be known from the LCP and the vegetation grids that were used to create it. In fact, the very best practice for maintaining fire modeling landscape data is to acquire, edit and update the data at the finest possible resolution (typically 30 m) and then resample to various coarser resolutions as needed.

Issues

After reprojecting spatial fire modeling landscape data to a coordinate system17 appropriate for the project, or after clipping the rectangular extent to the minimum required based on the fuelscape extent66 , certain issues can arise that can cause errors in FSim's raster results.

Excessive precision

One potential issue is excessive precision in the starting X-Y coordinates of the fire modeling landscape grids. Sometimes the .lcp will generate an extra column or row of data that is not present in the initial rasters--a shift of pixels by one row or column. This appears to be a more-common problem when using LFDAT than other tools, but we have run into issues with other .lcp-generating tools as well. We suggest taking any necessary step to eliminate all decimal places on the starting coordinates of the grids before generating an .lcp file. This step must be done after any reprojections, because that step is what introduces the excessive decimal places). Removing all decimal places isn't strictly necessary; removing all but 3-4 decimal places is usually sufficient. However, doing so drives home the point that our spatial data are certainly not mapped to sub-meter precision. Eliminating those decimals costs nothing in terms of spatial precision, and may alleviate possible bugs introduced when making the .lcp.

Dead rows or columns

Even without excessive precision in the grid coordinates, we occasionally encounter a pixel-shift in results compared to the inputs. For example, even after eliminating decimals from the fire modeling landscape ASCII rasters and making an LCP with the FlamMap utility, FSim produced a BP raster in which the results seemed to be shifted one pixel eastward. This is evident only by looking at the BP pattern around nonburnable features like lakes. Nonburnable features should have a BP of zero. With the shift, some pixels of fuel model 98 have a nonzero BP and some burnable area adjacent to the lake has a BP of 0. This was apparently caused by a "dead column" of data in the LCP. A dead column is an entire column within the rectangular extent that consists entirely of nodata values. FSim crops these dead rows and columns of data before performing its fire growth calculations. This cropping function may be introducing this error. Check for and eliminate dead rows and dead columns before generating an LCP.

Utilities for generating an LCP

There are several utilities available for generating an LCP from the component rasters. We have seen strange behavior with all if the utilities, but the most stable is the FlamMap LCP generator. FlamMap's challenge is that it requires ASCII rasters as input; it can't take ESRI grids or geodatabases or TIFFs as input. Below is a bit of information about each utility.

ArcFuels The ArcFuels extension to ArcMap includes a Build LCP utility for making an LCP from rasters. We do not have much experience with it, but in one case it seemed to insert extra columns of data into the LCP.

FARSITE Although FlamMap is the preferred Firelab-developed utility for making an LCP, FARSITE has a unique utility for *editing* an LCP that is not found in any other utility. It is useful for making quick (usually draft) edits to an LCP before making a final edit to the underlying fuel and vegetation grids at their finest resolution. You can modify landscape themes in FARSITE v.4 with the **Inputs > Landscape Utilities > Landscape Calculator** and **Inputs > Landscape Utilities > Edit Landscape** commands.

FlamMap The FlamMap .lcp-generating utility can only build an .lcp file from ASCII rasters. It can't source to a GeoTiff, ESRI grid or a raster in a geodatabase. If your fire modeling landscape rasters are in any of those formats you must first make ASCIIs before attempting to build an .lcp in FlamMap. When you have ASCIIs, open FlamMap and choose **File > Create Landscape (LCP) File...** LCP files generated with FlamMap have the fewest issues, but they require the extra step of first making ASCII rasters, which is significant if you have multiple FOAs, are making multiple resolutions, or anticipate making edits in ArcMap and then regenerating LCPs. FlamMap truncates (rounds down) the starting cell coordinates to an integer (feet or meters), even if the supplied ASCII rasters include decimals. This is fine, as the greatest possible shift in the fire modeling landscape is just 1 meter, which is well within the spatial error of all of the input layers.

LFDAT LFDAT--The LANDFIRE Data Access Tool--is a comprehensive utility for working with LANDFIRE data. It includes a utility for generating an LCP file from spatial data formats other than ASCII rasters (such as ESRI grids or a file geodatabase). LFDAT also has a utility for making grids from an LCP.

3.4.2 .frisk--Fire Risk file

The Fire Risk file (.frisk) file is a required input. It is an ASCII text file produced by FireFamilyPlus. The .frisk file contains information about historical weather conditions for the FSim project area. Specifically, the .frisk file has three sections (described in more detail below).

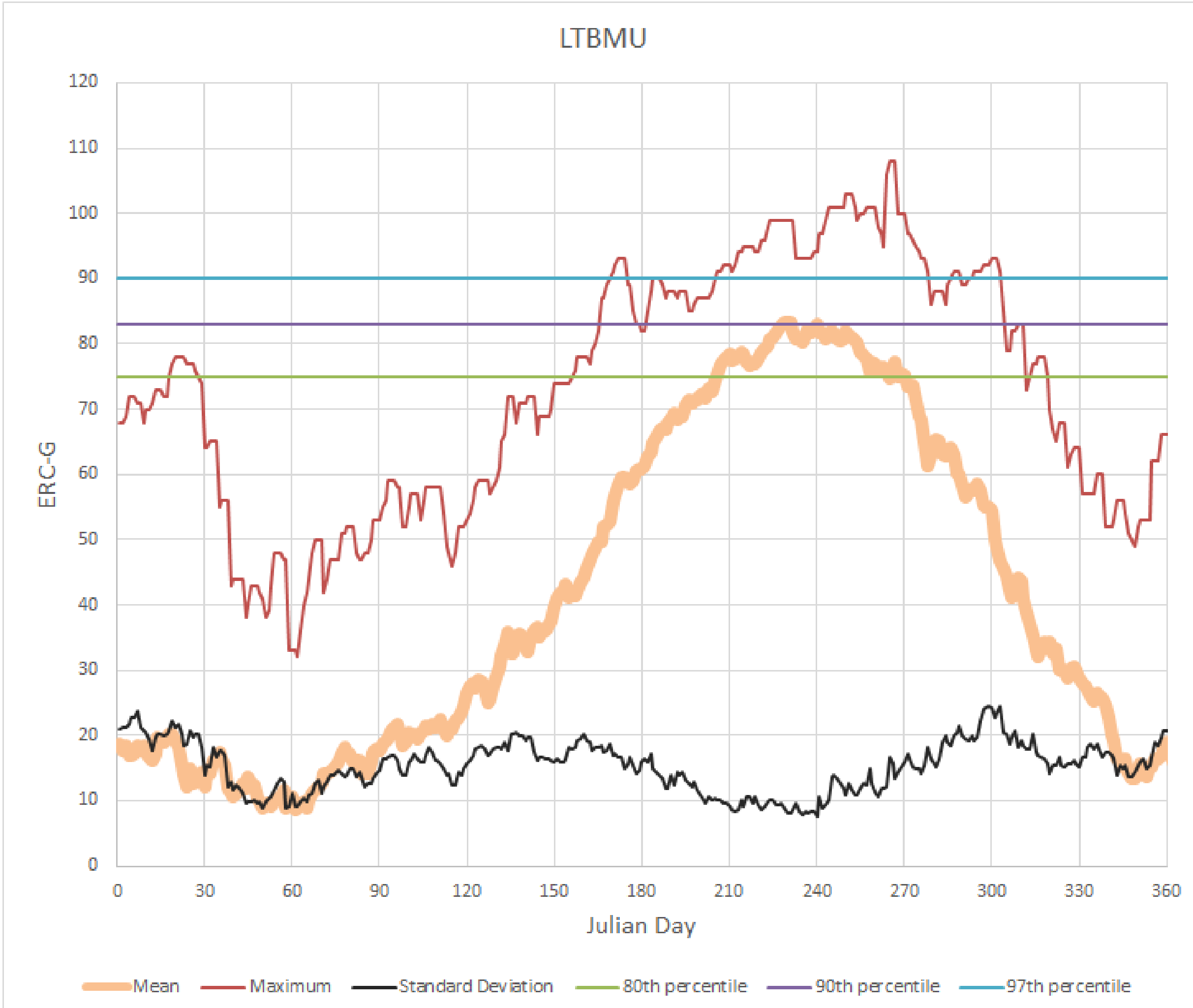
- Time Series Data
- Percentiles
- Wind Speed vs. Dir

FSim requires a year-round dataset of ERC, so be sure to choose a remote automated weather station (RAWS) that records data year round, not just during the fire season. Where daily weather values are missing, FireFamilyPlus will use the ERC value from the preceding day. FSim applies the distribution of wind speed and direction from the RAWS, so be sure to choose a RAWS that is fairly representative of the broader landscape. For example, a ridgetop or peak location may capture wind directions well, but could represent wind speeds higher than the landscape mean. A RAWS in a canyon or narrow valley can strongly influence both wind speed and direction and should be avoided. RAWS on a broad valley bottom or plateau are usually good for both wind speed and wind direction.

Sections of the .frisk file

Time Series Data

The TimeSeriesData section of the .frisk file contains information about historical daily ERC-G values. For each Julian Day, this section tabulates the mean and standard deviation of ERC. This section also lists the actual daily ERC values for each year of the historical period. FSim uses these daily ERC values to calculate the autocorrelation in daily ERC values, which is needed for simulating ERC. The daily values in the .frisk file were used to generate the following chart, which shows the seasonal trend (mean and standard deviation) in ERC along with the daily maximum ERC and the year-round 80th, 90th and 97th percentile values.



Percentiles

The Percentiles section contains information about the ERC and fuel moisture values associated with each percentile rank, from zero (the minimum value) to the 100th percentile (the maximum value). From this table, FSim plucks the 80th, 90th and 97th percentile ERC values (highlighted in dark gray). The percentiles are not labeled (the 'Pctle' column of the table does not exist in the .frisk file), but they are listed in order from 1 through 100 (a total of 100 rows). To find the 97th percentile ERC value, first find the bottom of the Percentiles table (just above the Wind Speed vs Dir header), the count up from the bottom. The last row of the section is the 100th percentile, so the 97th percentile is the fourth from the bottom. Continue counting up from the 97th percentile to the find the 90th and 80th percentile ERC values. In this .frisk file, the 80th percentile is 75, the 90th is 83 and the 97th is 90.

Pctle	ERC	1-h MC	10-h MC	100-h MC	1000-h M	HERB	WOODY	X1000
79	74	4.27	4.94	7.60	8.41	19.14	66.92	5.00
80	75	4.12	4.71	7.06	8.45	17.84	66.80	4.82
81	75.5	4.09	4.70	7.16	8.17	18.02	65.74	4.61
82	76	3.91	4.54	7.05	8.09	17.39	65.94	4.32
83	77	3.97	4.53	6.77	8.00	18.17	65.75	4.43

Pctle	ERC	1-h MC	10-h MC	100-h MC	1000-h M	HERB	WOODY	X1000
84	77.5	4.04	4.59	6.79	7.78	18.12	65.46	4.52
85	78	3.81	4.36	6.55	7.81	17.49	65.22	4.55
86	79	3.73	4.31	6.61	7.60	17.26	65.18	4.26
87	80	3.71	4.25	6.40	7.53	17.00	65.12	3.63
88	81	3.78	4.32	6.46	7.26	17.38	65.05	3.91
89	82	3.40	3.99	6.32	7.21	16.80	65.00	3.63
90	83	3.40	3.92	6.02	7.09	15.90	64.68	3.72
91	83.5	3.36	3.90	6.08	6.88	16.44	64.89	3.28
92	84.5	3.40	3.87	5.78	6.82	16.50	64.89	3.30
93	85	3.25	3.75	5.73	6.69	16.07	64.78	2.96
94	86	2.98	3.48	5.50	6.70	16.22	64.89	3.21
95	87	3.06	3.55	5.51	6.46	15.14	64.44	3.08
96	88	2.89	3.39	5.36	6.34	15.61	64.67	3.04
97	90	2.87	3.34	5.23	6.16	15.58	64.67	2.96
98	91	2.76	3.21	5.00	5.99	14.76	64.40	3.14
99	93.5	2.61	3.02	4.66	5.74	11.10	63.08	2.78
100	108	2.19	2.57	4.08	5.09	12.27	63.61	2.18

From this table FSim also plucks certain fuel moisture values. However, unlike the ERC values, the fuel moisture values are used to represent an ERC bin (80th to 90th, 90th to 97th and 97th to 100th), not the class breaks. For the 80th to 90th percentile bin, FSim uses the fuel moisture values for the 86th percentile; for the 90th to 97th percentile bin, it uses the fuel moisture values for the 95th percentile; and for the 97th and greater bin, it uses the 99th percentile values. The fuel moisture content values are truncated to zero decimal places (not rounded) for use in an .fms file. For example, the 1-h MC used for the 80th percentile ERC bin would be 3 percent, because the 86th percentile 1-h MC is 3.73. The 90th percentile bin would use 3 percent and the 97th percentile bin would use 2 percent for the 1-h MC. The moisture content values for the 10- and 100-h timelag classes and the live herbaceous and live woody components are determined similarly.

These default fuel moisture content values can be wholly or partially overridden by specifying fuel moisture contents by fuel model in the .fms files 45 .

Wind Speed vs Dir

The Wind Speed vs Dir section contains information about the joint distributions of wind speed and wind direction for each month of the year, and for the calendar year as a whole. If the monthly distributions are not present in the .frisk file, FSim will use the year-long distribution for all fires. If the monthly distributions are present, FSim uses the appropriate monthly distribution.

For example, below is one part of the Wind Speed vs Dir section (the distribution of wind speed and direction for the month of August):

```
August:
speed    45      90      135     180     225     270     315     360
5.00    0.78    0.61    1.34    4.20    6.16    1.91    2.10    3.06
10.00   1.61    1.72    1.68    4.37    29.20   11.80   3.48    5.07
15.00   0.32    0.30    0.30    0.61    8.11    2.86    0.25    0.38
20.00   0.00    0.00    0.00    0.00    0.08    0.00    0.00    0.00
25.00   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
30.00   0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
```

```
7.72
```

The first column of data represents the 20-ft wind speed in mi/h (5 to 30 mi/h in 5 mi/h increments) and the top row of data represents the wind direction in degrees clockwise from north (in 45 degree increments). These values reflect the direction the wind is coming from. The values in the body of the table represent the probabilities of the different combinations of wind speed and wind direction. The last row, containing only one value, is the probability of calm wind--zero wind speed (therefore no wind direction). The sum of the calm wind probability and the values in the body of the table is approximately 100. On any given day of a simulation, FSim draws the wind speed and direction stochastically from this table.

FSim uses the wind distribution tables exactly as presented. Note that FireFamilyPlus generates the table by assigning the observations to the upper end of the wind speed bin. For example, all wind speeds greater than 5 mi/h but less than or equal to 10 mi/h are assigned to the "10 mi/h" row. This presents a small upward bias in simulated wind speeds compared to historical.

Discussion

Issues

The .frisk file format is sensitive to keywords, as well as whitespace delimiters (tabs and spaces). Use extreme caution if attempting to build or edit a .frisk file in a text editor.

Utilities for generating a .frisk file

The .frisk file is generated in FireFamilyPlus.

3.4.3 .fdist--Fire-day distribution file

The Fire-day distribution file (.fdist) is a required input that is generated in FireFamilyPlus. It is an ASCII text file consisting of three inputs needed for the fire-occurrence module:

- logistic regression coefficients
- AcreFract
- Distribution of the number of large fires per large-fire day

The .fdist file is generated by FireFamilyPlus , but can also be created or edited in any text editor. For the LTBMU project, FireFamily Plus was used to generate the .fdist file:

```
coef1   -6.447446
coef2   0.032695
1.0 LargeFireProbabilityFactor
NumFires  NumTimes  1.0 <reserved>
1       76
2       2
```

The top two rows are the logistic regression coefficients, which are used as follows to determine the probability of a large-fire day (where a large-fire day is defined as a day on which at least one large fire ignites):

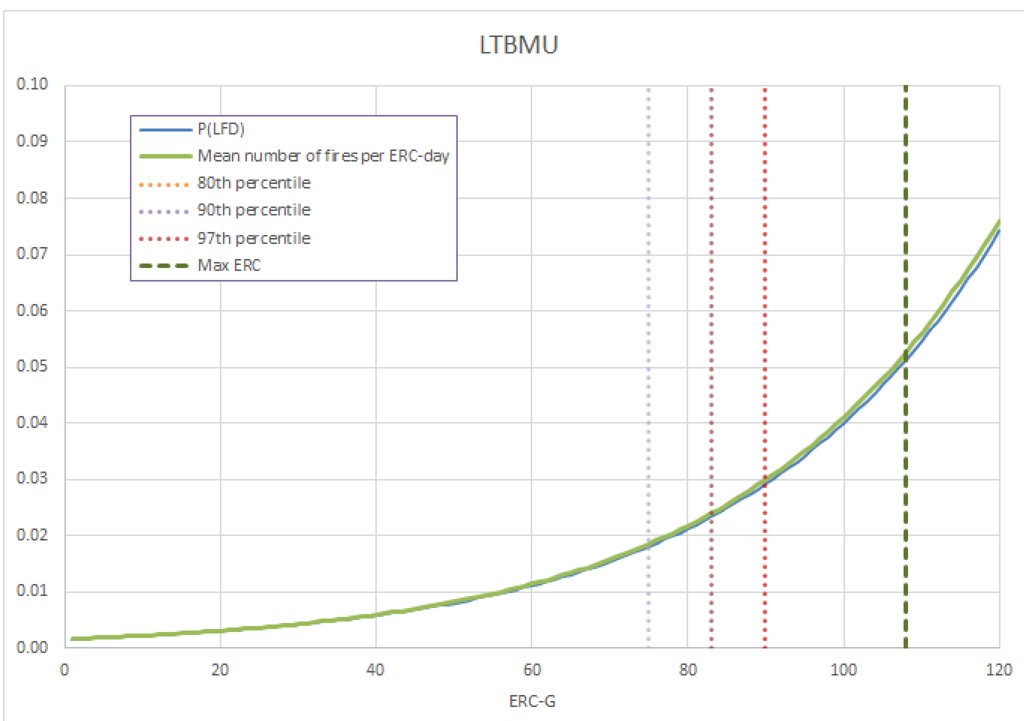
P(LFD) = 1/(1+e^(6.447446-0.032695*ERC))

where P(LFD) is the probability of at least one large fire igniting on this day, and ERC is the ERC-G value for the day.

The next line lists the "LargeFireProbabilityFactor", commonly known as AcreFract. The default from FireFamilyPlus (FFPlus) is 1.0, but the true default is the ratio of the historical fire occurrence area to the fire simulation fire-occurrence area. That is, sometimes, especially in the past when fire occurrence data were not readily available across all land ownerships, it was common to have fire occurrence data for only a portion of the area for which fires would be simulated in FSim. If data were available for only half of the area, then the AcreFract would be 0.50. AcreFract is a divisor on the probability of a large-fire day. An AcreFract of 0.5 doubles the probability of a large-fire day as determined from the logistic regression alone.

The next line, beginning with "NumFires NumTimes...", is a header for the table below. DO NOT EDIT ANYTHING IN THIS HEADER. The table below is the historical distribution of the number of fires per large-fire day. In this .fdist file, there were 80 large fires occurring on 78 large-fire days. On 76 of those days there was just one large fire discovered, and on two days there were two fires started. There were never three or more large fires discovered on the same day. The mean of this distribution--the mean number of large fires per large-fire day--is important. Here, it is 80/78, or 1.025. The mean is calculated as the sumproduct of the two columns (NumFires*NumTimes) divided by the sum of the second column (NumTimes).

Those three pieces of information come together into a plot of large-fire probability in relation to ERC (below). The vertical dotted reference lines indicate the 80th, 90th, and 97th percentile ERC values. The dashed vertical reference line is the maximum ERC value during the historical period. The light blue line is the probability of a large-fire day as calculated with the logistic regression coefficients. Because AcreFract is 1.0, there is no adjustment on this probability. The light green line represents the mean number of fires per ERC-day. It is the product of the probability of a large-fire day and the mean number of fires per large-fire day. In this example, there are only an average of 1.025 large fires per large-fire day, so these lines are nearly identical.



Discussion

Issues

The following header row within the .fdist file

```
NumFires  NumTimes  1.0 <reserved>
```

contains a value (1.0) that is read by FSim but otherwise not used. Do not edit this value of 1.0 on this line.

Utilities for generating an .fdist file

The .fdist file can be generated in FireFamilyPlus. It can be readily edited in a text editor, or generated with a scripting program, such as 'R'. Please see Appendix A for information about generating an FDist file with FireFamilyPlus.

3.4.4 .fms--Fuel moisture inputs file

The fuel moisture content files (.fms) are optional inputs. They are ASCII text files that indicate the 1-, 10- and 100-h timelag class dead fuel moisture content and live herbaceous and live woody moisture content values to use for each fire behavior fuel model. The .fms files are in the same format as the files used in FARSITE and FlamMap; see the help files for those programs for more information. There can be up to three .fms files for a simulation, one for each of three ERC bins: 80th, 90th and 97th percentiles.

Nominal ERC bin	Percentile ERC values in bin	Percentile value used for FMS (read from .frisk)	filename for actual simulation fuel moisture content values	Suggested input filename
80th	80-89	86th	fsim_default_2.fms	[PROJECT]v1_80.fms
90th	90-96	95th	fsim_default_1.fms	[PROJECT]v1_90.fms
97th	97+	99th	fsim_default_0.fms	[PROJECT]v1_97.fms

By default, if no .fms files are supplied, FSim reads live and dead fuel moisture content values from the FRISK file 40. The 86th percentile live and dead fuel moisture values are used for the 80th percentile ERC bin; the 95th percentile values for the 90th percentile ERC bin, and the 99th percentile values for the 97th percentile ERC bin. All fuel models are given these default fuel moisture values.

The optional .fms input files are used to override some or all of the live or dead fuel moisture content values, for some or all of the fuel models on the landscape. Among FSim's standard outputs is a set of three "fsim_default_X.fms" files. This set of three files indicate the fuel moisture content values actually used in the simulation. Any fuel model not listed in the input .fms file is assigned fuel moisture contents from the .frisk. For listed fuel models, any live or dead component with -1 for the moisture content is assigned fuel moisture contents from the .frisk.

```
101 -1 -1 -1 40 60
102 -1 -1 -1 40 60
103 -1 -1 -1 40 60
104 -1 -1 -1 40 60
121 -1 -1 -1 40 60
122 -1 -1 -1 40 60
141 -1 -1 -1 40 60
142 -1 -1 -1 40 60
143 -1 -1 -1 40 60
```

```
145 -1 -1 -1 40 60
147 -1 -1 -1 40 60
161 -1 -1 -1 40 60
162 -1 -1 -1 40 60
165 -1 -1 -1 40 60
181 -1 -1 -1 40 60
182 -1 -1 -1 40 60
183 -1 -1 -1 40 60
185 -1 -1 -1 40 60
186 -1 -1 -1 40 60
188 -1 -1 -1 40 60
202 -1 -1 -1 40 60
```

For the LTBMU project, we let FSim pluck the dead fuel moisture content values from the .frisk file, but overrode the live herbaceous and live woody values as follows:

Nominal ERC bin	1-h MC	10-h M	100-h MC	live HERB	live WOODY
80th	-1	-1	-1	90	110
90th	-1	-1	-1	60	80
97th	-1	-1	-1	40	60

These MC values were applied to all fuel models.

Discussion

Issues

Even if you wish to use the dead fuel moisture content values from the .frisk file, the live herbaceous and live woody moisture content values from the .frisk are rarely reasonable. You should always override the live fuel MCs using the three .fms files. The table above shows reasonable live fuel moisture content values to use for the 80th, 90th, and 97th percentile ERC bins.

If custom fuel models are used in the .lcp, be sure to add a record for that fuel model in the .fms input files. If you don't, they will be given the default values from the .frisk file.

The percentile fuel moisture contents in the .frisk file represent the aspect, elevation and exposure (canopy cover) of the RAWS location. By default, FSim applies these RAWS-location values to all fuel models across the entire landscape. RAWS are typically in open-canopy areas, so the dead fuel moisture content values in the .frisk do not reflect the influence of a forest canopy on dead fuel moisture content. To reflect higher dead fuel MC in beneath a forest canopy, you may wish to simply add 1-2 percentage points to the 1-, 10- and 100-h timelag moisture content values for fuel models that are typically associated with a forest canopy (the TU, TL and SB fuel types). An advanced option is to use dead fuel moisture conditioning in FlamMap to produce a raster of relative 1-hr dead fuel moisture content (relative to the RAWS location) for typical afternoon fire-season weather conditions. Then run Zonal Stats on this raster, with fuel model as the zone, and use the resulting table of mean values by fuel model to adjust the RAWS-based defaults.

Utilities for generating FMS files

The .fms files can be generated in any text editor, or even in a generated in a spreadsheet and then copied and pasted into a text editor. FARSITE includes a custom .fms file editor, but it is not usually worthwhile to use that custom editor because the file format is so simple.

3.4.5 _idg.asc--Ignition Density Grid

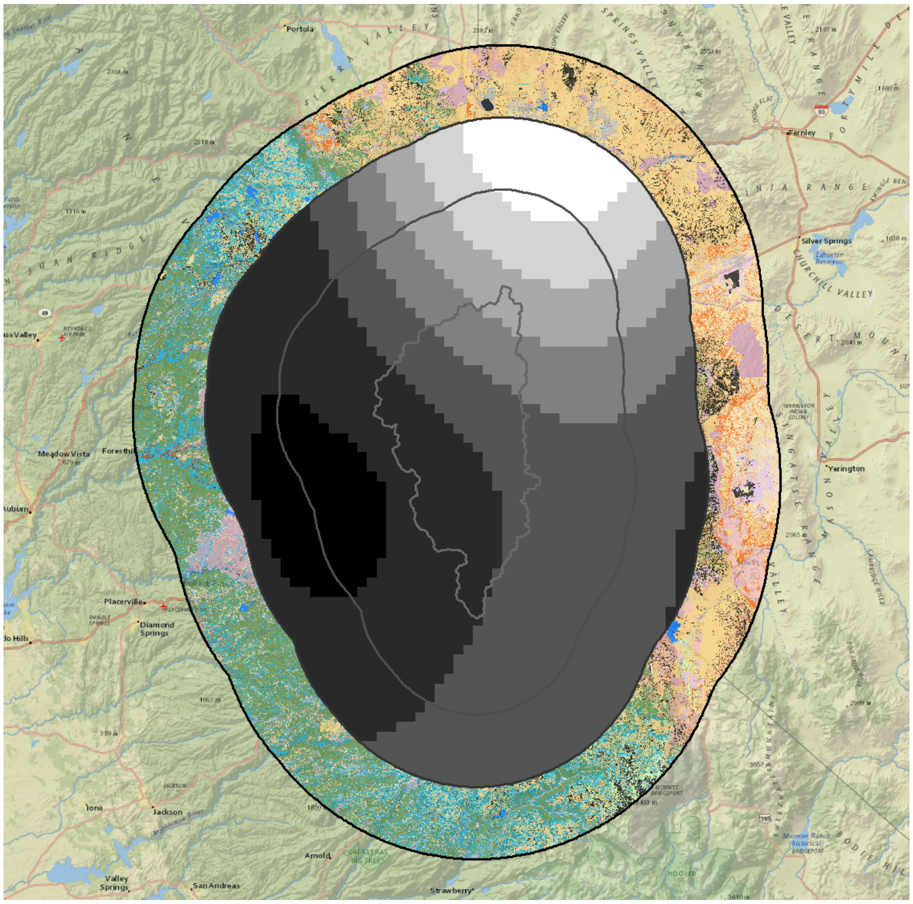
FSim accommodates an optional ignition density grid (IDG) to indicate the spatial likelihood of large-fire occurrence. The ignition density grid (or _idg.asc) is a raster-format spatial dataset representing the *relative* density of large-fire ignitions across the landscape. The values in the IDG are used relative to one other, not in any absolute sense. In fact, the first thing FSim does is normalize the IDG so that the highest value within the modeling extent is 1.0--all other pixel values are a fraction relative to the maximum.

The IDG should indicate the spatial density of large fires, not fires of all sizes. The subset of all fires that become large may occur in different locations on the landscape than where small fires occur. A great number of fires start where people occupy the landscape, but these are also the places where fire suppression resources are located or can reach quickly, keeping those fires small. Because FSim is concerned with the simulation of large fires, it is important that the IDG reflect where large fires occur.

There are a few criteria for the ignition density grid:

- It must be in the same projected coordinate system[17] used for the LCP
- It must be in ASCII raster format
- It need not be co-registered with or of the same cell size as the LCP
- in fact, the IDG **must** have a larger extent than the LCP

For the LTBMU project, we generated an IDG by first obtaining a spatial large-fire occurrence database for a large area around the FOA (to accommodate a large search radius when making a density grid). We then used the Kernel Density tool with a 75-km search radius and 2-km output cell size, we resampled that raster to 120-m resolution, set all values outside of the FOA polygon to zero, and exported the grid as an ASCII raster. This prevents FSim from starting fires outside the FOA boundary even if there is fire modeling landscape data there. The figure below illustrates the extent of nonzero IDG values in relation to the fire modeling landscape, FOA, analysis area (AA) and land management unit (LMU) boundaries. On this landscape, the area of relatively higher ignition density corresponds to the region around Reno, Nevada, where human population leads to a large number of ignitions that become large.



On the map above, zero values are excluded from the legend and do not show. Those zero values cover an area much larger than the fire modeling landscape extent, which is a requirement for the IDG to function properly.

Discussion

Issues

The IDG is sensitive to any number of potential errors that could cause the IDG to be ignored. It is good practice to plot the simulated start locations and verify that the pattern matches the IDG.

To function properly in FSim, the IDG must have a larger extent than the .lcp file. We found that at least one "extra" row and column in the IDG (on the top, bottom, left and right side of the .lcp file) alleviates any issues.

Although the IDG need not use the same cell size as the LCP, there are no problems with doing so as long as the IDG is sufficiently larger than the LCP.

There is a known issue with the IDG in versions of FSim through b1.22. The IDG value in a given IDG pixel is applied to the IDG pixel to its immediate south. Using a finer pixel size for the IDG mitigates this issue until the error is corrected. The same issue applies to the Ignition Mask[25] .

Utilities for generating an IDG

It is relatively easy to build your own IDG in ArcGIS using the kernel density tool. We suggest a maximum 2-km cell size, 75-km search radius and 100-ha (247.1-ac) large-fire size threshold. After you make the IDG, plot the large-fire start locations on top of the IDG to visually verify the IDG. Avoid using too fine a search radius (which produces "pimples" of high probability around individual fires). Avoid too much uniformity, too, which can occur with an excessive search radius, large cell size, or not using a kernel function. Remember that your IDG must be larger in extent than the LCP it will be used with, and that you need historical large-fire occurrence data for a large area around the LCP in order to avoid an edge effect. After making the IDG, reproject it to the coordinate system of the LCP, if necessary, and export it as an ASCII raster.

3.4.6 .fmd--custom fuel model file

Custom fuel models are not commonly used in FSim, but are available for use if desired. Please see the FARSITE and FlamMap documentation for the proper format and use of custom fuel models in an .lcp file. Be aware that using a custom fuel model in FSim also requires FMS [45] and ADJ [49] values; if omitted from the input files, FSim will apply a default value for the custom fuel model. Also be aware that the numbering of the custom fuel models will influence FSim's containment module as described here [29].

3.4.7 .adj--Rate of spread adjustment-factor file

FSim accommodates the optional use of surface fire spread rate adjustment factors identical to those developed for the FARSITE fire growth model. The adjustment factors are specified in a text file (.adj) for each fuel model on the landscape. If no .adj file is specified for an FSim run, then the spread rate predicted by the Rothermel model is used without adjustment.

The following ADJ values are reasonable "default" factors to use for an initial simulation. Default factors of 1.0 tend to produce extremely large fires. A value of 0.9 in the .adj means that spread rate is 90% of that predicted by Rothermel, and fire sizes will be approximately 0.9^2 or 81% of their size at ADJ=1. This listing includes all 40 of the Scott and Burgan fuel models. If your fire modeling landscape includes custom fuel models or any of the original 13 fuel models, be sure to include those fuel model numbers in the ADJ file.

```
101     0.25
102     0.25
103     0.25
104     0.25
105     0.25
106     0.25
107     0.25
108     0.25
109     0.25
121     0.25
122     0.25
123     0.25
124     0.25
141     0.40
142     0.40
143     0.40
144     0.40
145     0.40
146     0.40
147     0.40
148     0.40
```

```
149     0.40
161     0.40
162     0.40
163     0.40
164     0.40
165     0.40
181     0.40
182     0.40
183     0.40
184     0.40
185     0.40
186     0.40
187     0.40
188     0.40
189     0.40
201     0.40
202     0.40
203     0.40
204     0.40
```

Fireline intensity and flame length are not adjusted by these ROS adjustment factors, so transition to crown fire is also not influenced by these factors. Surface ROS adjustment factors are useful for calibrating the sizes of fires occurring in different parts of the landscape. Other calibration approaches include modifying the fuel moisture contents for individual fuel models, which affects both spread rate and intensity, and adjusting the perimeter trimming coefficient, which can reduce fire sizes by simulating more aggressive containment.

Discussion

Issues

If a fuel model exists in the .lcp but is not listed in the .adj file, a value of 1.0 will be used for that fuel model. If a forest canopy is present, the values in the .adj file operate on the "final" spread rate, whether that is a surface fire, passive crown fire or active crown fire.

Using the default values of 1.0 for all fuel models usually overpredicts fire sizes, often dramatically. That's a good place to start for an initial simulation, but it is likely that tighter values will be required. Options for tightening adj values in this file include:

- making a very broad adjustment--the same adj for all fuel models
- making somewhat broad adjustments--the same adj value for a fuel type (GR/GS, SH, TU/TL/SB)
- making narrow adjustments--a different adj for each fuel model

Tighter adj values are usually needed on GR/GS fuel models than on SH and TL/TU fuel models, even with crown fire modeling included.

Utilities for generating an .adj file

The .adj file is a simple space-delimited text file that can be generated or edited in any text editor.

The FSim calibration[108] workbook included with this guide includes a worksheet that can be used to quickly edit an existing .adj using Excel's traditional copy-and-paste commands.

3.4.8 _barrier.shp--Barrier shape file

Barriers are available for use in FSim, but this feature remains untested. Please see the FARSITE and FlamMap documentation for the proper format and use of the _barrier.shp file.

3.4.9 _mask.asc--Ignition Mask

An ignition mask is an ASCII raster used to limit the area within which FSim will start fires. The ignition mask is designed to produce raster results generated from fires originating from only a portion of the landscape. For instance, the annual burn probability associated with fires originating on federal land can be simulated with this feature. This feature is only needed to produce the raster results. FSim's fire size list and fire perimeter results include information about each fire's start location, so those results can be used to generate summaries of area burned by ownership-at-origin.

Cells in the ignition mask are identified as true or false. Any cell value greater than or equal to 0.5 is true; any value less than 0.5 is false. We suggest using a value of 1 for true and 0 for false. FSIM will disregard any ignitions occurring where the attempted ignition has a mask value of false (0).

The mask can be used on simulation with "record: 1" (record fresh ignitions) or with "record: 0" (replay previously recorded ignitions). In both cases, an ignition is rejected *without* replacement. That is, after FSim goes through its normal routine for locating an ignition on the landscape, it will reject ignitions for which the mask value is false (0) and not find a replacement location for which the mask value is true (1). In the normal routine, FSim rejects any ignition location that is not over a burnable fuel model, then stochastically rejects locations based on the relative ignition density grid. This behavior with the ignition mask contrasts with setting a value of zero in the ignition density grid. Where the IDG value is zero, FSim will reject all ignitions there, but will find a suitable location elsewhere on the landscape (*with* replacement).

Discussion

The ignition mask must be in ASCII raster format, just like the ignition density grid [47] . It must use the same spatial reference [17] as the .lcp file, and the ignition mask must cover the entire LCP area.

Issues

There is a known issue with the Ignition Mask in versions of FSim through b1.22. The IDG value in a given Ignition Mask pixel is applied to the pixel to its immediate south. Using a finer pixel size for the Ignition Mask partially mitigates this issue until the error is corrected. The same issue applies to the Ignition Density Grid [25].

Utilities for generating an ignition mask

Use ArcGIS or other GIS software to generate the ignition mask.

3.4.10 .erc--ERC stream file

An .erc file is a text file consisting of predetermined ERC values for a number of simulated 365-day years. The ERC stream begins on Julian day 1. This FSim feature is used only for coordinating simulated ERC among adjacent FOAs, a topic not covered in this guide. When the .erc file is specified in the command file [25] , FSim uses the values supplied in the .erc file rather than generating values from information in the time series data portion of the .frisk file [40].

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FSim output files

4 FSim output files

In this section we describe the standard FSim outputs, and options for processing them.

4.1 Burn probability

The primary FSim output is a raster of burn probability (*BP)* produced at the resolution specified in the command file. FSim estimates annual *BP*--the likelihood of burning during a one-year period. The *BP* raster is produced in ASCII raster format with no projection information. The correct projection is the projected coordinate system (PCS) that was used for the fire modeling landscape. It is a good practice to assign the correct projection to this raster and save it in another format, such as a GeoTIFF, ESRI grid or file geodatabase.

FSim's _BurnProb (for burn probability, or BP) output is the annual probability of fire burning each pixel across the landscape. It is calculated for a given pixel by dividing the number of times a fire burns the pixel by the number of iterations in the simulation. For example, if a given pixel burns 68 times in 10,000 iterations, the BP for that pixel is 68/10,000 = 0.0068.

The ASCII raster begins with a standard header:

```
ncols 975
nrows 1638
xllcorner -321881.000000
yllcorner 6194.000000
cellsize 180.000000
NODATA_VALUE -9999
```

Below this header are the *BP* data in space-delimited format.

4.2 Mean fireline intensity

FSim's MeanIntensity output (for mean fireline intensity, or MFI) is the conditional mean fireline intensity (kW/m) at each pixel across the landscape. It is calculated for a given pixel by summing the fireline intensity values for each fire that burned a given pixel and dividing by the number of times a fire burned the pixel. In other words, it is the arithmetic mean fireline intensity (not counting the iterations that did not burn the pixel).

The _MeanIntensity.asc output file is an ASCII raster indicating MFI for all pixels across the landscape. The ASCII raster begins with the same standard header as the burn probability raster described above.

FSim does not produce coordinate system information for this raster. Its coordinate system is identical to the projected coordinate system used for the .lcp file. It is a good practice to assign the correct projection to this raster and save it in another format, such as a GeoTIFF, ESRI grid or file geodatabase.

4.3 Flame-length probability

FSim produces information about potential flame length. FSim calculates the conditional probabilities of observing defined flame-length classes, called flame-length probability (*FLP*). FSim uses six flame-length classes (called Fire Intensity Levels, or FILs). Rather than directly produce *FLP* rasters, FSim produces an

"*FLP* text file" that identifies the six *FLP* values and X-Y coordinates for every pixel on the landscape. Geoprocessing is required to convert the *FLP* text file into a usable set of *FLP* rasters.

Fire Intensity Level	Flame length (ft)
FIL1	0-2
FIL2	2-4
FIL3	4-6
FIL4	6-8
FIL5	8-12
FIL6	12+

For the FLP text file, the grid of cells associated with the _BurnProb and _MeanIntensity rasters are represented as points. Each row in the FLP text file represents a point (or cell), and lists the X-Y coordinates for the point, PBurn (equivalent to BurnProb), and the conditional flame-length probability for FIL1 through FIL6. The conditional probabilities across the six flame lengths sum to 1 if the pixel burned or 0 if it did not burn during the simulation.

The FLP text file is produced in CSV format. An example is shown below, for just a few points.

```
         XPos,           YPos,    PBurn,     FIL1,     FIL2,     FIL3,     FIL4,     FIL5,
FIL6
-280211.000000, 256124.000000, 0.010367, 0.153846, 0.326923, 0.250000, 0.230769, 0.019231,
0.019231
-280031.000000, 256124.000000, 0.010566, 0.009434, 0.179245, 0.273585, 0.207547, 0.216981,
0.113208
-279851.000000, 256124.000000, 0.010766, 0.000000, 0.101852, 0.074074, 0.324074, 0.314815,
0.185185
-279671.000000, 256124.000000, 0.010865, 0.009174, 0.229358, 0.275229, 0.165138, 0.183486,
0.137615
-279491.000000, 256124.000000, 0.010766, 0.000000, 0.120370, 0.555556, 0.203704, 0.101852,
0.018519
-279311.000000, 256124.000000, 0.009769, 0.020408, 0.316327, 0.153061, 0.459184, 0.051020,
0.000000
-279131.000000, 256124.000000, 0.005183, 0.115385, 0.846154, 0.019231, 0.019231, 0.000000,
0.000000
-278951.000000, 256124.000000, 0.004884, 0.142857, 0.836735, 0.000000, 0.020408, 0.000000,
0.000000
-278771.000000, 256124.000000, 0.005283, 0.075472, 0.924528, 0.000000, 0.000000, 0.000000,
0.000000
-278591.000000, 256124.000000, 0.006180, 0.000000, 1.000000, 0.000000, 0.000000, 0.000000,
0.000000
```

Like the _BurnProb and _MeanIntensity rasters, it is best practice to generate rasters for the FLPs and assign projection information.

4.4 Event set (perimeters)

In addition to the raster-format burn probability and conditional fire intensity outputs described above, FSim can also save as output the final perimeter of each simulated wildfire. These perimeters are saved as polygons in one or more ESRI Shapefiles. The attribute table provided with each shapefile indicates several important characteristics of each wildfire, including:

	Field	Type	Width	Decimals
1)	FIRE_NUMBE	Integer	16	0
2)	THREAD_NUM	Integer	16	0

3)	ERC_STARTD	Integer	16	0
4)	ERC_PERCEN	Integer	16	0
5)	NUM_BURNDA	Integer	16	0
6)	START_DAY	Integer	16	0
7)	YEAR	Integer	16	0
8)	SizeAc	Double	16	0
9)	Xcoord	Double	18	6
10)	Ycoord	Double	18	6
11)	CONTAIN	String	19	0

- FIRE_NUMBE is the unique fire number for a simulation; good across all threads.
- THREAD_NUM is the thread number that simulated the fire (the number of threads is determined by the number of CPUs in the workstation, the number of processing cores per CPU, and whether the cores are hyperthreaded.)
- ERC_STARTD is the ERC(G) on the start day of the fire.
- ERC_PERCEN is the ERC(G) percentile associated with ERC_STARTD. The ERC_PERCEN is a simple lookup from the ERC_STARTD from the "percentiles" section of the .frisk file.
- NUM_BURNDA is the number of days the fire burned during the simulation. This does not include any no-burn days (days below the 80th percentile ERC).
- START_DAY is the Julian day of the fire start
- YEAR is the iteration number (year) for which the fire was simulated
- SizeAc is the final fire size (acres) based on a count of pixels that burned (it does not include non-burnable pixels or pixels that did not burn but were entirely within the final fire perimeter). This field may vary from the fire's area calculated from its associated perimeter.
- Xcoord/Ycoord are the coordinates of the fire's ignition point
- CONTAIN is the reason for the cessation of fire growth on the simulated fire.

The CONTAIN field is only populated on freshly recorded (record: 1) simulations; on record: 0 simulations the result for all fires is 'NA'. For a run with suppression OFF (Suppression: 0) the valid field values are:

- NoContain--the fire was potentially active at Julian Day 365 (if the ERC is at or above the 80th percentile)
- NonBurnableExceeded--the fire exceeded the consecutive number of nonburn days specified by the NoSuppressionNonBurnDaysLimit switch

For a run with suppression ON (Suppression: 1) the valid field values are:

- NoContain--the fire was uncontained at Julian Day 365
- 2DayLimitExceeded--the fire started in non-timber fuel and encountered more than two consecutive nonburn days
- 7DayLimitExceeded--the fire started in timber fuel and encountered more than seven consecutive nonburn days
- NonTimberStochastic--the fire started in non-timber fuel and was contained by the non-timber stochastic model
- TimberStochastic--the fire started in timber fuel and was contained by the timber-based stochastic model

For the purpose of the containment model, the timber/non-timber flag is set by the surface fire behavior fuel model at the ignition location. Fuel models 1 through 7 and 14 through 160 are flagged as non-timber; fuel models 8 through 13 and 161 through 256 are flagged as timber.

This set of simulated final perimeters with associated attributes represents an "event set" for the fire occurrence area. A wildfire event set is a set of N elements (events) generated by a stochastic simulator as possible future outcomes of wildfire occurrence, growth and behavior. With stochastic wildfire simulations, an event is the result for one complete wildfire season, during which any number of wildfires—including zero—may have been simulated to occur. Each event has an annual probability of occurring of 1/N, where N is the number of iterations in the simulation.

The ESRI Shapefiles do not include any spatial reference information. The spatial reference for this set of perimeters is the same as the spatial reference for the fire modeling landscape. It is a best practice to assign the correct spatial reference to these Shapefiles before conducting any analyses to ensure compatibility with data that use other spatial references. The FSim post-processing script provided with this guide performs this assignment of projection information.

The information available for each event in the set can be extended by GIS analysis to summarize conditional fire effects within each perimeter. For example, if a raster representing the sediment volume produced if a wildfire occurs, then summing the values within a perimeter is the total volume produced by the simulated wildfire, which can then become an additional attribute of the event set.

4.5 Ember outputs

Ember outputs are a new feature of FSim b1.21 (December 2016). These outputs have not yet been thoroughly tested. The outputs can be generated in CSV or ESRI Shapefile formats, or both. The ember outputs do not seem to impose a significant computation-time penalty, but the outputs can take a LOT of disk space.

The ember outputs consist of five fields, as follows:

- FireID
- LaunchX
- LaunchY
- LandX
- LandY

Where the FireID is linked to the FireID in the FireSizeList. LaunchX/Y are the coordinates of the ember launch location and LandX/Y are the coordinates of the ember landing location. Only nodes that generate passive or active crown fire can launch embers. The landing location need not be burnable; these outputs show the ember landing location regardless of whether the ember did or even could ignite a spot fire.

4.6 Fire-size list

In addition to the attribute table associated with the optional ESRI Shapefile of final fire perimeters, FSim also produces a _FireSizeList.txt file with similar individual-fire information. The _FireSizeList.txt file does not have header information. It lists 11 fields for each simulated fire, in the following order:

1. THREAD_NUM
2. Xcoord
3. Ycoord

4. NUM_BURNDA
5. SizeAc
6. YEAR
7. START_DAY
8. ERC_STARTD
9. BURN_MIN (total number of minutes of fire growth)
10. FIRE_NUMBE
11. CONTAIN

Please see the Event Set (perimeters) topic for details on these fields.

4.7 Progress text file

FSim can produce an optional progress text file that is continuously updated throughout a simulation. The name and path for this file is specified in the command file with the ProgressFilePathname[32] switch. During the early part of a simulation (e.g. when FlamMap is running) the file contains text that says "Initializing...". During the risk calculations, the file shows the fraction of iterations for which simulation has started (not finished). After the simulation is completed the file will still read "1.0000 started", meaning that 100 percent of the iterations were started. Because some iterations can take a very long time to complete, the file may read "1.0000 started" long before the simulation finally finishes.

You can use the fraction displayed in the progress text file to make estimates of total simulation time and completion time. We have found that the actual temporal progress toward completion of the simulation is sometimes not quite linear with the stated progress. This could be due to the fact that iterations with low ERCs have few fires and are completed very quickly (showing great progress), but iterations with high ERCs tend to have a lot of fires, with longer than average durations and sizes.

We recommend generating a progress text file for every simulation.

4.8 Timings file

The timings file is an ASCII text file with outputs indicating how long it took the simulation to run, the command file used, and the FSim version number. The listed version number was not correct when using versions b119 and b120; timings files for both of those versions indicate b118 was used. This was corrected in version b121.

The root of the timings file is the filename specified in the OutputsName switch in the command file; "_timings.txt" is appended to that root name. The duration of calculations for several "splits" are noted:

- preparation runtime
- FlamMap runtime
- Risk (FSim) runtime
- Total runtime

An example timings file is shown below.

```
Timings file for FSIM version B1.18
Inputs command file: foa27r6.cmdx
Prep Runtime: 0.317000 secs
FlamMap Runtime: 82.045000 secs
RISK Runtime: 30751.501000 secs
```

Total Runtime: 30833.863000 secs

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Setting up FSim

5 Setting up FSim

This section of the guide covers setting up an FSim run from scratch. The section includes an interpreted example for the Lake Tahoe Basin Management Unit (LTBMU) of the USDA Forest Service. All primary and ancillary datasets needed to follow the example as a tutorial are available at the link below. In addition to the raw input datasets, the "school-solution" FSim inputs are also provided. The FSim calibration section that follows uses the school-solution inputs.

Among the very first steps in setting up an FSim project is the selection of a coordinate system[17] to use for all spatial data. We typically begin by querying staff of the land management unit to find out what coordinate system may be the standard. That standard is typically acceptable for use with FSim.

The Lake Tahoe Basin Management Unit example we will use the NAD 83 California Teale Albers coordinate system for all spatial inputs and outputs.

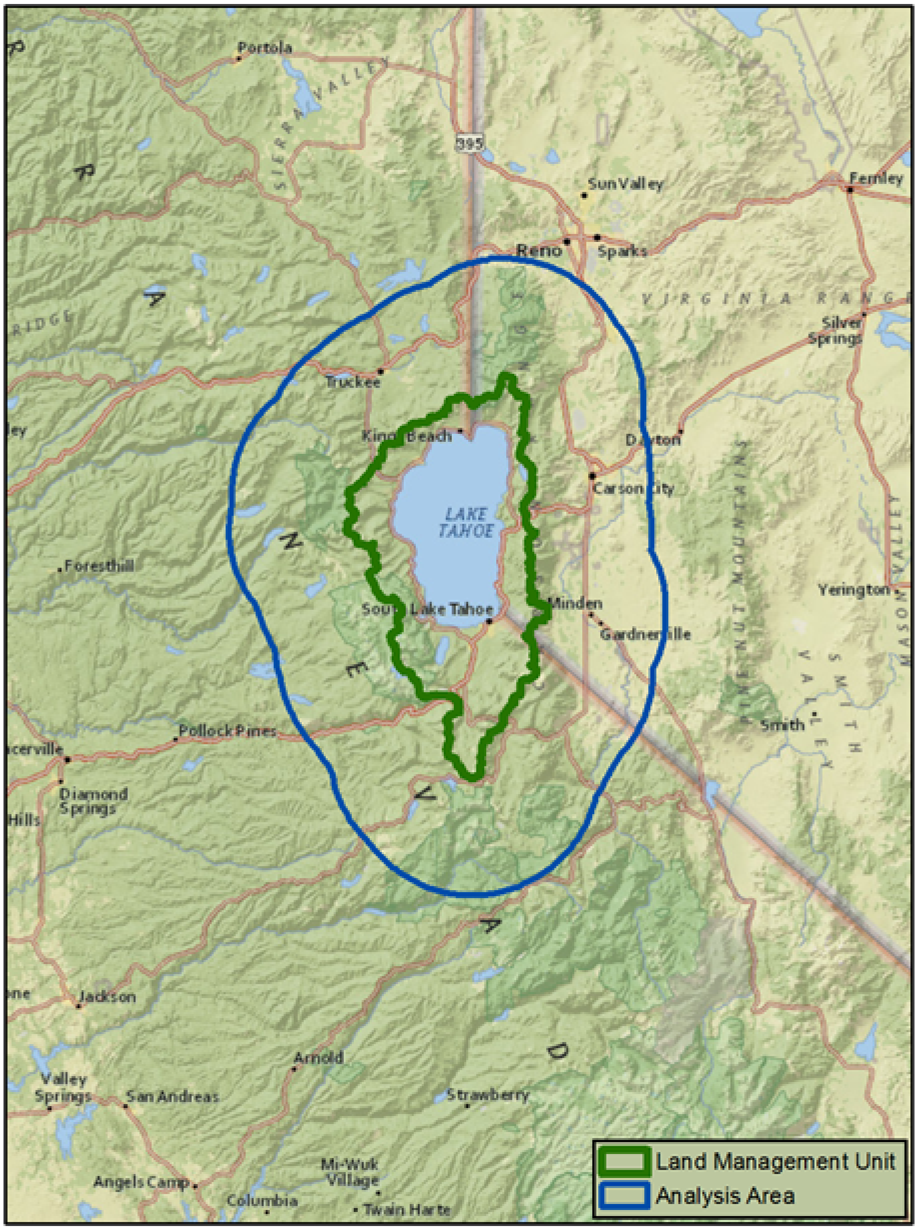
5.1 Setting the zones

We will illustrate the process of setting up an FSim run using an example project. For the example, the FSim assessment will be for the Lake Tahoe Basin Management Unit (LTBMU), which surrounds Lake Tahoe, about 50 km south-southwest of Reno, Nevada.

5.1.1 Land Management Unit (LMU)

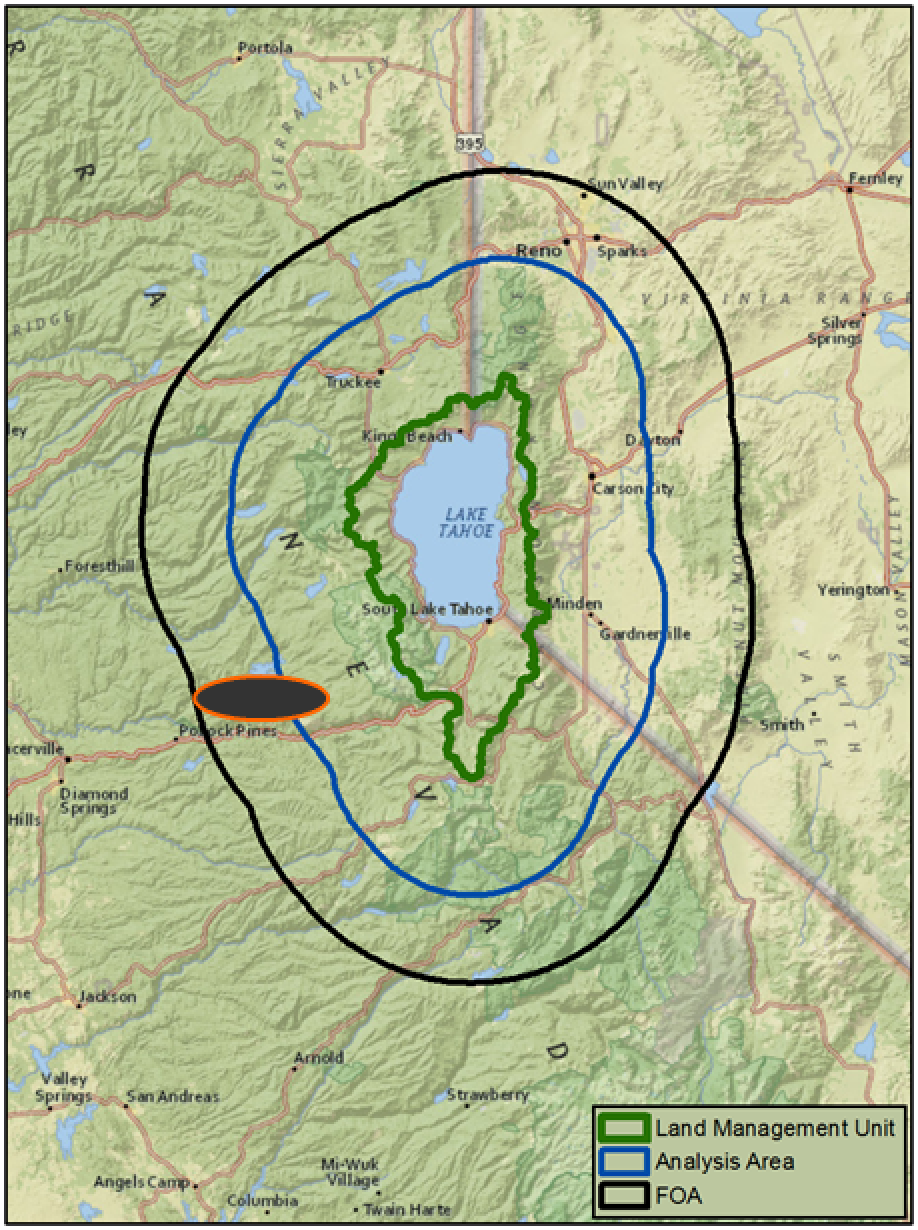
Setting the zones for an FSim project starts with the land management unit (LMU) for which the assessment is being conducted. In our example, the LMU is the Lake Tahoe Basin Management Unit, which encompasses 330,000 acres (including 123,000 acres of Lake Tahoe itself).

5.1.2 Analysis Area (AA) extent



The LMU is the absolute minimum area for which valid FSim results are desired, but, for most purposes, it is a good idea to produce valid results for a buffer around the LMU, so that the results for the LMU can be seen in the context of the surrounding landscape. This larger area of desired results is called the Analysis Area (AA). The buffer can be anywhere from 5 to 30 km around the LMU. For our example, we show the are showing the AA as a 20-km buffer around the Lake Tahoe Basin Management Unit. It covers 1.5 million acres.

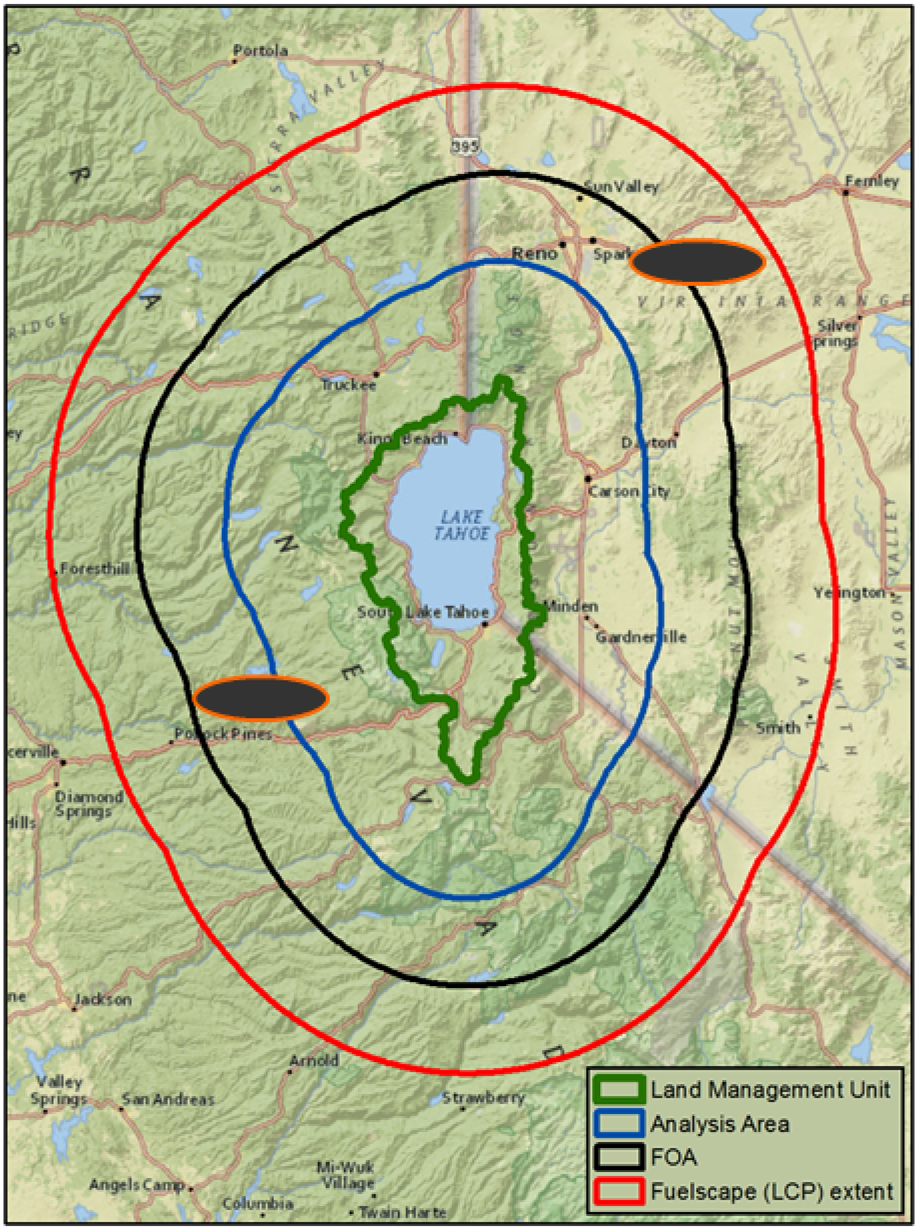
5.1.3 Fire Occurrence Area (FOA) extent



Because FSim simulates large-fire growth, producing valid FSim results for the AA requires starting fires well outside of the AA and letting them burn into it. This larger area is called the Fire Occurrence Area; it is the area within which we will have FSim start its simulated fires. The FOA extent is determined by adding a buffer to the AA that is large enough to encompass the largest fires that may occur. This buffer is typically 15-30 km. In our example, the FOA extent is a 15-km buffer on the AA. The FOA encompasses 2.73 million acres.

We will use this FOA extent to perform the historical fire occurrence analysis and to set up the FSim fire occurrence inputs. We will use the IDG input to allow FSim to start fires within the FOA but not outside of it.

5.1.4 Fuelscape (LCP) extent



We will use a customized IDG to start fires only within the FOA extent, but those fires should be allowed to spread outward from all parts of the FOA, so yet another buffer is required to determine the desired fire modeling landscape (LCP) extent. This buffer is typically the same size as the AA-to-FOA buffer, about 15-30 km. If this buffer is not included, then fires starting in the FOA could be artificially limited by the edge of the LCP data, potentially biasing the fire-size distribution. In that case, you would need to clip all fires starting outside of the AA before calculating the fire-size distribution. We find it much simpler to provide a little extra LCP extent. When using multiple FOAs for a project, this extra LCP is required for the "natural weighting" method of compiling multiple FOAs.

In this example, the fire modeling landscape extent is a 15-km buffer on the FOA, encompassing 4.3 million acres.

Operating FSim

6 Operating FSim

FSim is a Windows command-line executable program. This section provides information regarding best-practices for operating FSim.

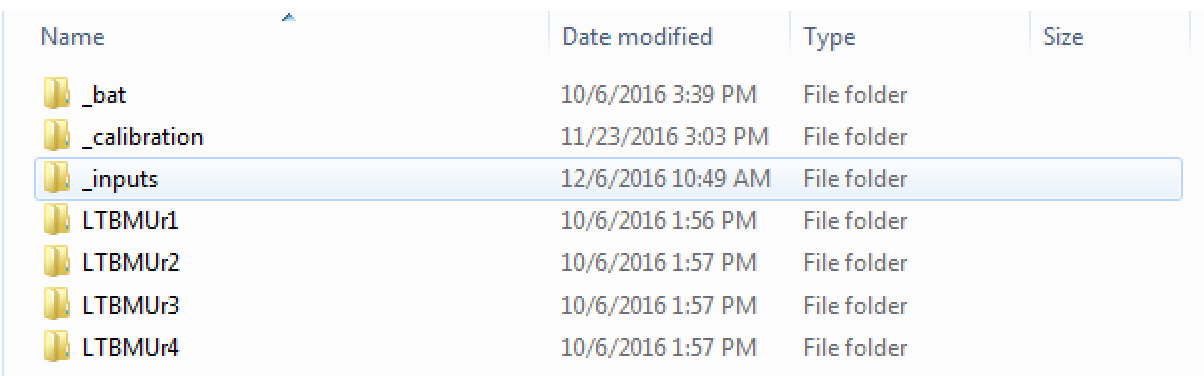
6.1 Folder structure

Using a standardized folder structure provides excellent documentation of the inputs and calibration process used for an FSim project. In years past, keeping all FSim inputs and run files for all calibration runs would have been storage-space prohibitive. Today, storage space is incredibly cheap, so keep everything until you're sure you won't ever need to refer to it again.

The folder structure for an FSim project includes several components:

- Executables folder
- _bat folder
- _calibration folder
- _inputs folder
- Run folders (one folder for each run)

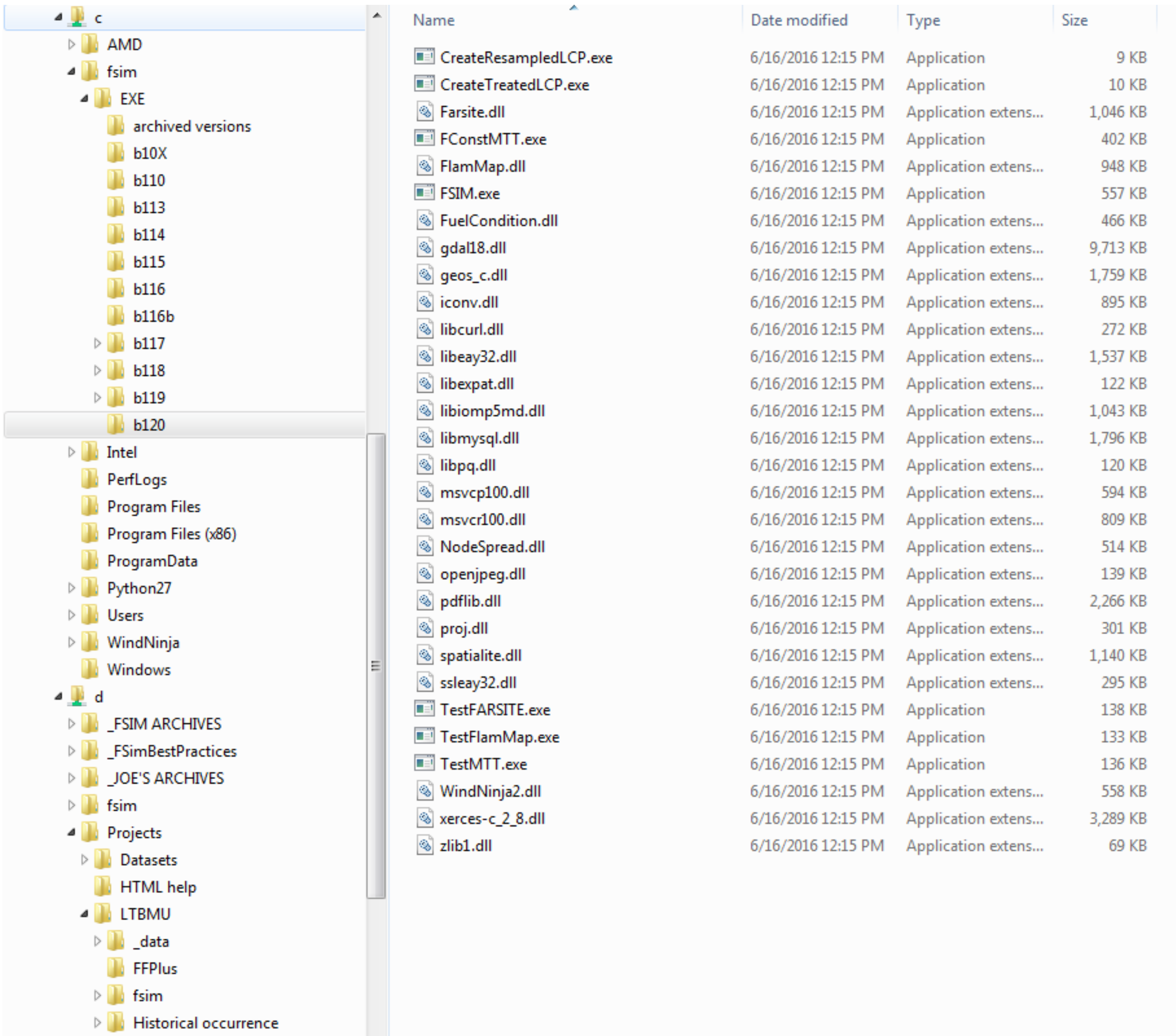
Each of these folders is described in the following sections.



6.1.1 Executables

FSim's executables can be stored anywhere on the FSim workstation. We recommend maintaining a folder of FSim executables on the C:\ drive of the workstation, even if the inputs and outputs are on a separate storage drive. Keep successive versions of FSim in different folders so that you can, if necessary, easily run any version. When executing FSim from a Windows BAT file, you can easily set a PATH to the folder containing executables for the version you want to run.

For example, we keep the FSim executables on the C:\ drive of each FSim workstation. Each new FSim version goes in its own folder labeled with the version number. For this guide, we are using version b1.20, so the folder is C:\FSim\EXE\b120\.



6.1.2 _bat

The _bat folder contains the Windows Batch files (.bat) that are used to execute one or more FSim runs. These .bat files can exist anywhere on the FSim workstation, but we suggest keeping them in a dedicated folder within the project.

6.1.3 _calibration

The _calibration folder contains any calibration spreadsheets or map documents (.mxd) used to compare simulated and historical fire occurrence and to track the results of each simulation.

6.1.4 _inputs

Inputs for an FSim run should be stored in a \PROJECT\fsim_inputs\ folder, with subfolders for the ten different input types. These inputs should not be in the same folder as the executables, and they should not even be in the same folder as the command file. In fact, the inputs can be stored on a different workstation within a local-area network, or even in a Dropbox folder. In addition to the ten FSim input file types, we recommend also using a folder to store a projection file (.prj) that contains the spatial reference information for the LCP.

For our example, all of the inputs for a simulation for the Lake Tahoe Basin Management Unit (LTBMU) are stored on a storage drive on the FSim workstation—Z:\LTBMU\fsim_inputs\. We use subfolders for each input type, even though some inputs will only have one version, or will perhaps even be unused. We find this format facilitates the use of different versions, as needed, during calibration.

Name	Date modified	Type
adj	4/21/2016 3:10 PM	File folder
barrier	12/21/2016 2:48 PM	File folder
erc	4/22/2016 3:10 PM	File folder
fdist	4/21/2016 3:10 PM	File folder
fmd	12/21/2016 2:48 PM	File folder
fms	4/21/2016 3:10 PM	File folder
frisk	4/21/2016 3:10 PM	File folder
idg	4/21/2016 3:10 PM	File folder
lcp	4/21/2016 3:10 PM	File folder
mask	12/21/2016 2:49 PM	File folder
prj	12/21/2016 2:49 PM	File folder

6.1.5 Runs

Each FSim run should have its own run folder. At the start of a record = 1 simulation, the only file in the run folder will be the command file--we store the inputs in a separate folder and the executables are in a folder on the C:\ drive. If the record feature is turned off (meaning that information about fires and weather are read from a previous simulation), then FSim also needs the full set of burndaysXX.bin files and frisk_randomXX.txt files that contain the preciously recorded weather and fire occurrence information. Despite the duplication of burndays.bin and frisk_random.txt files, we recommend copying these files to a new folder for a record-off run, rather than running the record-off simulations in the same folder. If running in the same folder, a simple error in the command file could result in overwriting the burndays.bin and frisk_random.txt files.

Name	Date modified	Type	Size
_bat	10/6/2016 3:39 PM	File folder	
_calibration	11/23/2016 3:03 PM	File folder	
_inputs	12/6/2016 10:49 AM	File folder	
LTBMUr1	10/6/2016 1:56 PM	File folder	
LTBMUr2	10/6/2016 1:57 PM	File folder	
LTBMUr3	10/6/2016 1:57 PM	File folder	
LTBMUr4	10/6/2016 1:57 PM	File folder	

6.2 Executing FSim

FSim is a command-line executable program, so it is executed from the Command Prompt. However, it is far better to run FSim from a Windows "batch" file (.bat), a text file that lists Windows commands. The .bat file provides a record of the commands used to run FSim and is repeatable in the event that a run needs to be rerun. Windows executes the commands in the order they appear in the .bat file, from the top of the file on down. Each command is executed only after the previous command has been completed.

```
PATH=C:\FSim\EXE\b120\
CD Z:\Projects\LTBMU\fsim\LTBMUr1
FSim > LTBMUr1_version.txt
FSim LTBMUr1.cmdx
```

The first line of this .bat file sets the path to the version of FSim you want to use. We store alternative versions in different folders labeled with the version number. We set this path in the .bat file rather than globally in Windows so that we can easily run different versions for different runs, as necessary.

The second line is a "change directory" command, telling Windows to change focus to the listed folder. Use the full path if necessary; other change-directory commands can be used to change focus to the desired folder, depending on the exact folder structure. Before this command, Windows' focus will be on the folder containing the .bat file.

The third line causes FSim to execute without a command file, which is a prompt for FSim to display version information along with usage syntax. By piping the resulting text to a text file (" > LTBMUr1_version.txt"), you create a text file with a record of which version of FSim was used for the simulation. This information could be critical when, years later, you need to re-do the simulation and want to be sure to use the same version.

The fourth and last line of the .bat file is the one that actually executes the simulation. The listed command file must be in the folder to which the focus was directed in the change-directory command in the second line. That command file will contain references to specific inputs files, so be sure the double check the path and filenames for those input files.

6.3 Troubleshooting

FSim is not a "mature" piece of software with robust error-checking. In fact FSim is quite robust in the opposite sense--it is designed to move past potential errors and finish anyway. And, in most cases, it won't provide any indication it did that. If you input an invalid switch parameter, FSim may ignore the parameter and proceed with the default value. If you specify an optional input file that is not correctly formatted or not found in the location specified, FSim will ignore the input and proceed without it.

So, troubleshooting FSim is required for every single simulation. Be wary of any unexpected result you get.

6.3.1 When FSim fails to run

Because FSim has so many inputs, each with a specific format, it is not uncommon for FSim to fail to run when executed. When FSim fails to execute, it writes text to the screen with an indication of the problem--the *first* problem encountered; if there are additional problems, you will find them only after finding and fixing the first problem. If you're running FSim from a .bat file, none of this text will be seen, as the FSim window will close immediately. In that case, you need to edit the .bat file to save the screen result to a text file.

```
PATH=C:\FSim\EXE\b120\
CD D:\Projects\LTBMU\LTBMUr1
FSim > LTBMUr1.version
FSim LTBMUr1.cmdx > whatistheproblem.txt
```

Now the screen output will be piped into a text file called `whatistheproblem.txt` and saved in the run folder. Open that file and scroll to the very bottom; there will be a message indicating what the problem is. For example, at the bottom of that file you might see this line of text:

```
Error loading FSIM inputs:

        Can't Open file. - LTBMUr1.cmdx
```

This error message typically indicates that FSim is not finding the specified file. In this case, the command file is not being found. Check the .bat file for the correct spelling of the path and filename. For our example .bat file shown above, the command file `LTBMUr1.cmdx` should be located in the `D:\Projects\LTBMU\LTBMUr1` folder.

Let's say you find that indeed the command file was not where it was supposed to be, and that you moved the command file to the correct location. Before doing anything else, remove the piping to `whatistheproblem.txt` in the .bat file, because you don't want all screen content for a full non-failed run piped into a text file. Now execute the BAT file again. If it fails again, restore the piping to `whatistheproblem.txt`, run the .bat file again and check the `whatistheproblem.txt` file again. Now you see this:

```
Error loading FSIM inputs:

        Can't Open file. - command file switch and file name:

landscape: LTBMU1v1.lcp
```

This error message indicates that there is a problem opening the LCP file. The referenced line is from the command file, which means that FSim is indeed finding and opening the command file, so that's good. Open the command file to confirm that is the line, then examine the spelling and syntax of the switch and the referenced filename. In this case, the actual LCP file is named `LTBMUv1.lcp`, but the command file referenced `LTBMU1v1.lcp`. Fix the command file setting and continue.

Note that only some FSim errors result in a failure to run. FSim is very robust in that most input errors result in FSim finding a way to move forward with the simulation (usually relying on the default setting, or omitting an optional input). FSim does not create a log of what inputs were actually used in a simulation, so there is little way to know whether your ignition density grid, for example, was used in the simulation. The onus is on the user to verify that the simulation settings and inputs were used as expected.

Calibrating FSim

7 Calibrating FSim

FSim calibration is the modification of FSim inputs or settings such that the simulated fire occurrence is within acceptable range of historical values. Several measures can be used to compare historical and simulated fire occurrence for agreement.

- number of large fires per year
- number of large-fire acres burned per year
- Mean (or median) annual large-fire burn probability
- Mean (or median) large-fire size
- Agreement with the historical fire-size distribution

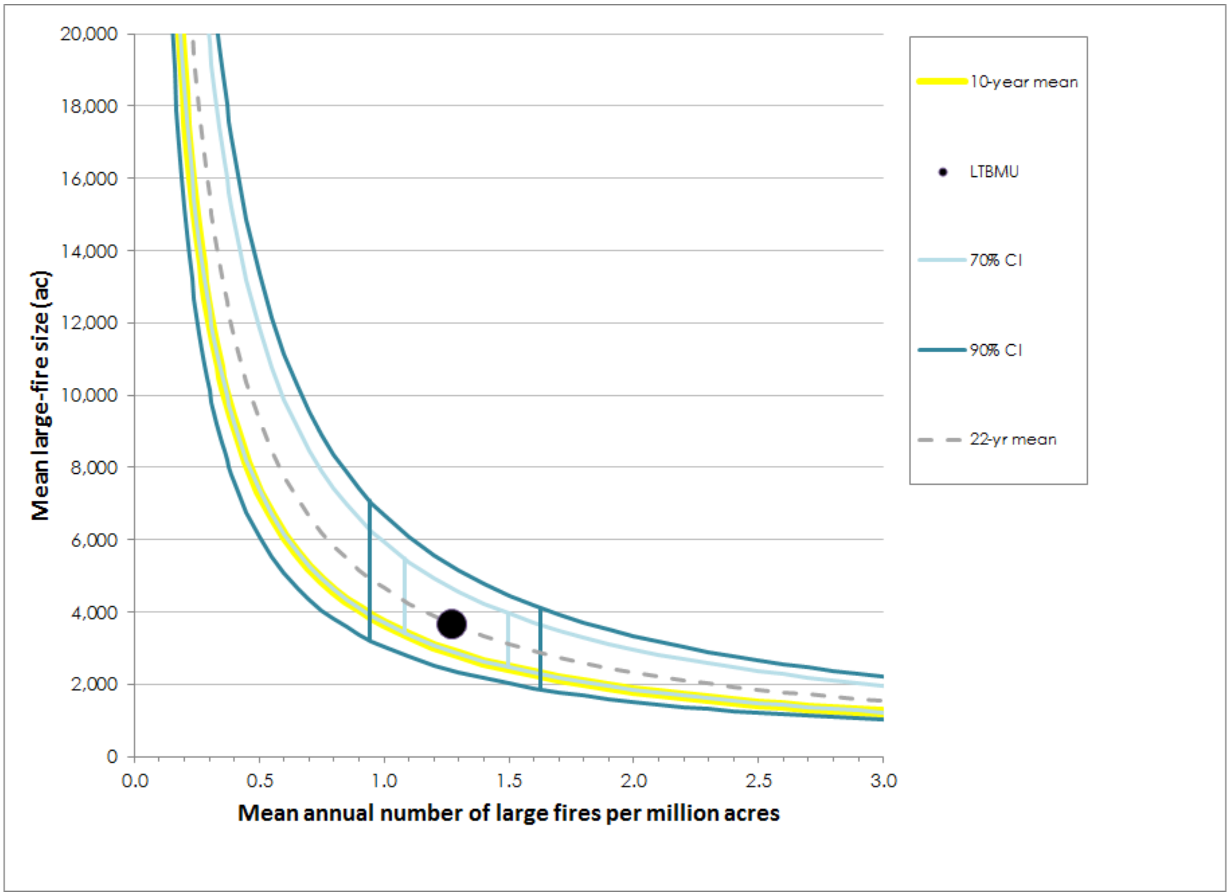
Several of these measures are inherently related. An analysis of FSim simulations showed that the slope of the log-log fire-size distribution is strongly related to the mean large-fire size. Steeper slopes are correlated with a smaller mean large-fire size. Therefore it is not necessary to calibrate both mean large-fire size and the slope of the distribution--either of those is sufficient. We prefer to calibrate for large-fire size, primarily for its easy calculation.

Also, the product of the number of large fires per year and the mean large-fire size equals the number of acres burned per year. Calibrating any two of those measures will inherently bring the third into calibration as well. Historical calibration targets are easily determined for the mean (or median) annual number of large fires and the mean annual large-fire area burned. However, FSim's inputs control mean annual number of large fires and their mean size. The calibration process is about changing these two measures, even if the desire is to control annual area burned and burn probability.

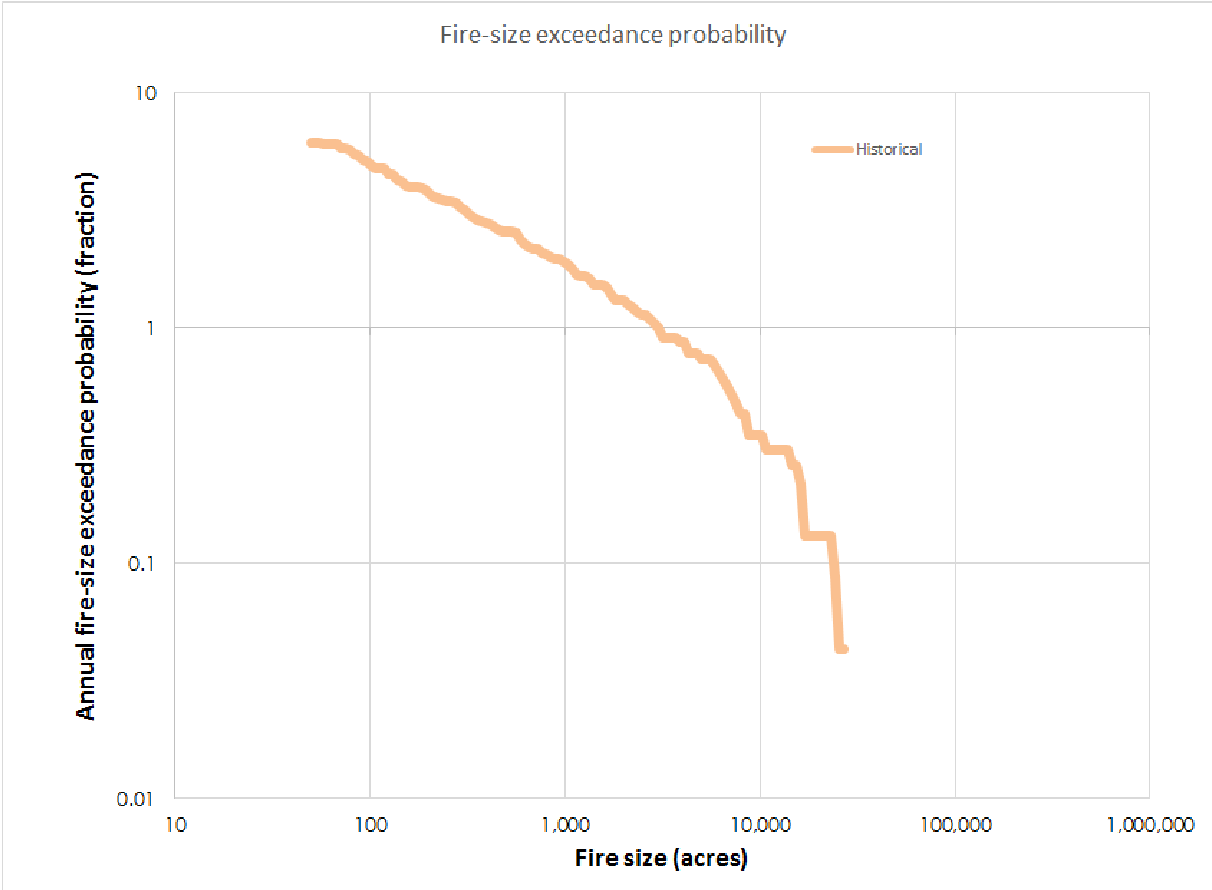
7.1 Historical targets

When clibrating an FSim simulation, how close to historical values of fire occurrence is close enough? One way to judge that is to use bootstrapped confidence intervals on the mean annual number of large fires and mean annual large-fire area burned. From a simple large-fire occurrence database it is possible to estimate the 70% and 90% confidence intervals around the means of those measures. A goal of FSim calibration is to ensure the simulated number of large fires and annual large-fire area burned are within the 70% confidence intervals.

For example, the chart below shows, as the black dot, the mean annual number of large fires (per million acres, so that FOAs of different sizes can be plotted reliably) and the corresponding mean large-fire size that would produce the historical mean annual area burned for the Lake Tahoe Basin Management Unit (LTBMU). Around the dot are the 70% and 90% confidence intervals. Later, during calibration, the results of FSim simulations can be plotted on this same chart. In the 2.73 million acre FOA, there were 80 large fires during the 23-year period 1992-2014, an average of 1.3 large fires per million acres per year. Over the same period, large fires burned a total of 292,716 acres, an average of 12,717 acres per year. Over the 2.73-million-acre FOA, that is 4,654 acres burned per million acres per year, which is a FOA-mean burn probability of 0.00465. The mean size of large fires was 3,659 acres. The chart below shows this data point along with the 70% and 90% confidence intervals around the mean. The most-recent 10-year average annual acres burned is shown as a yellow line. This line represents all combinations of number and sizes of large fires that result in the 10-year mean annual area burned rather than just a point representing the exact values for the most-recent 10-year period. In this case, the 10-year mean annual area burned happens to coincide with the lower 70% confidence interval on the 23-year mean.



Another way to illustrate historical fire occurrence is through a fire-size exceedance probability (EP) chart. The fire-size EP chart below (both axes are in logarithmic scale) shows the annual probability of exceeding various fire-size thresholds based on the 23-year historical record. The Y-axis can also be read as the expected annual number of fires exceeding the X-axis value. The simulated fire-size distribution can be plotted on the same chart for a visual comparison of historical and simulated fire size distributions.



Our calibration goal is for the simulated mean annual number and mean size of large-fires to be within the 70% confidence interval as shown on the top chart, and for the simulated fire-size distribution to match the historical distribution, as shown on the bottom chart, as well as possible.

7.2 Process

As mentioned above, the FSim calibration process entails dialing-in just two fire-occurrence measures: annual number of large fires and their mean (or median) size (or the fire-size distribution). Calibrating the number of large fires in FSim is relatively simple and predictable. Calibrating large-fire size is not as straightforward and usually requires a cut-and-try approach.

Adjusting inputs to calibrate large-fire size tends to affect the number of large-fires (by affecting the fraction of starts that reach the large-fire size threshold). For example, reducing rate of spread means that a greater number of the ignitions in FSim will not grow large enough to qualify as large fires. The inverse is not true--methods for calibrating the number of large fires (such as adjusting the acrefract) have little effect on large-fire size. Therefore, we recommend focusing early calibration efforts on large-fire size and the fire-size distribution, and then, once the fire-size distribution is within acceptable range, on the number of large fires. With practice, you may be able to predict the effects of calibrating large-fire size on large-fire number and make calibration changes to both at once.

An analyst usually has a target final resolution in mind for an FSim run. On occasion, it is possible to do all calibration at that resolution. In most cases it will be most expedient to do the initial calibration runs at a coarser resolution and then step down to the final resolution after the results are closer to historical. Don't bother dialing the coarser simulations too well, because both the number and mean size of large fires can change when switching resolutions. We've seen such changes when going from 270 to 180 m resolution, and from 180 to 120 m resolution. These changes due to resolution are not necessarily predictable.

7.3 Calibrating large-fire size

Adjusting inputs to calibrate mean large-fire size is challenging as there are many potential inputs and settings to adjust, including:

- rate of spread adjustment factors
- the suppression module settings
- the fire modeling landscape (primarily fuel model and canopy base height)
- live and dead fuel moisture contents
- percentile ERC values and wind speed options
- the fire-size limit

We discuss the adjustment of each of these inputs or settings in the following sections.

7.3.1 Using the .adj file

An .adj file is a rate-of-spread (ROS) adjustment factor file. It is an ASCII text file listing fuel model numbers and an associated adjustment factor for each listed fuel model. The ROS adjustment factors modify the spread rate simulated with the Rothermel surface and crown fire models by the specified value. The default is 1.0, meaning that the model-predicted spread rate is used without modification. Adjustment factors greater than 1 would increase surface fire spread rate; factors less than 1 will reduce it. The adjustment factors are specified separately for each fuel model. The adjustment factor for any fuel model number not listed in the .adj file is 1.0.

The ROS adjustment factors do not affect fireline intensity or flame length, and therefore do not affect the transition to crowning. In fact, the ROS adjustment factors are applied to the final ROS after the transition to crowning has been simulated.

All other settings held constant, using adjustment factors less than 1 will result in a smaller mean large-fire size. The number of large fires will decrease as well since fewer fires will cross the large-fire size threshold because of the lower spread rates.

The relationship between ROS and area burned is exponential, not linear. In other words, doubling the ROS roughly quadruples the area burned (and by extension the BP). Because of this relationship, the effect of ADJ values on BP and area burned is also not linear, but is somewhat predictable. If a given set of ADJ values produces a mean fire size of X, and the desired mean size is Y, then try multiplying all ADJ values by the SQRT(X/Y). For example, to reduce fire size by half, multiply the ADJ values by SQRT(0.5), or 0.707. This approach works only approximately, but it is usually helpful to keep in mind. As seen in the sensitivity analysis below, this exponential model would hold well if it weren't for the changing number of large fires with a change in ADJ values.

Typically, it is desirable to reduce fire size in a portion of the landscape but not others. For example, large expanses of grassland or grass-shrublands tend to result in very large fires in FSim. It is common to require stronger ADJ values in GR/GS fuel models than in other fuel types. When using the ADJ file to adjust large-fire size, consider a three-level approach:

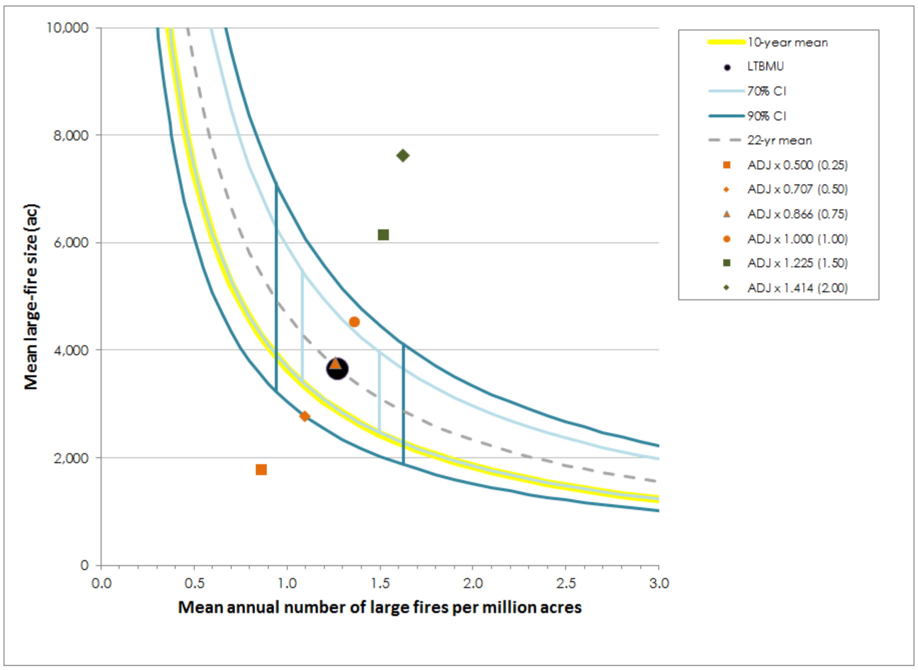
- Adjust ADJ values globally (all fuel models)

- Adjust ADJ values by fuel type or fuel-type group (e.g., GR/GS, SH and TU/TL/SB)
- Adjust ADJ values for specific fuel models

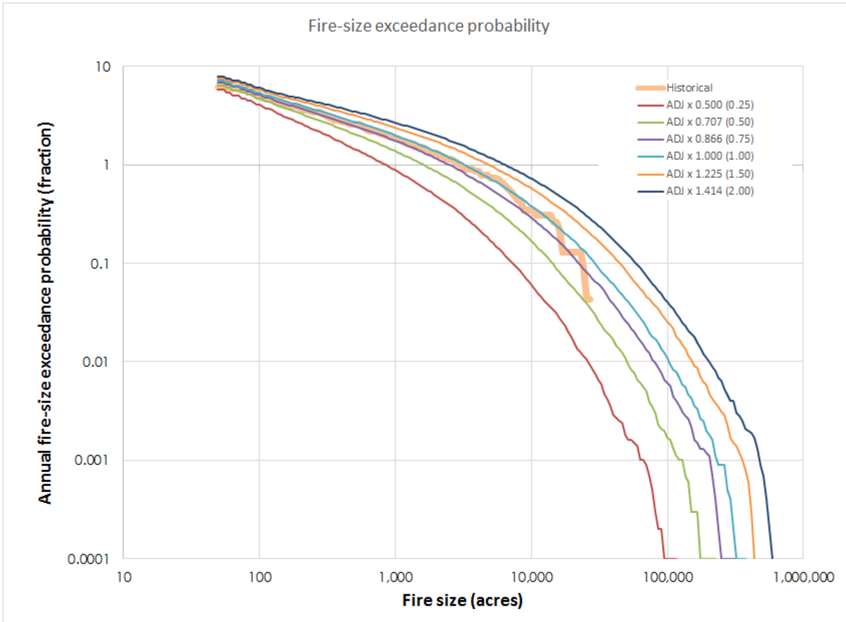
To illustrate the effects of ROS adjustment factors on the number and sizes of large fires we set up a sensitivity analysis using Record: 0 (replay start locations and weather) to isolate the effects of the ROS adjustment factors. Starting from ADJ values used for the LTBMU 180-m simulation, we made a set of four additional .adj files. Each of those new .adj files represents a multiplier on the baseline. The ADJ multipliers (and associated approximate effect on fire size) were:

- 0.500 (0.25)
- 0.707 (0.50)
- 0.866 (0.75)
- 1.000 (1.00)
- 1.225 (1.50)
- 1.414 (2.00)

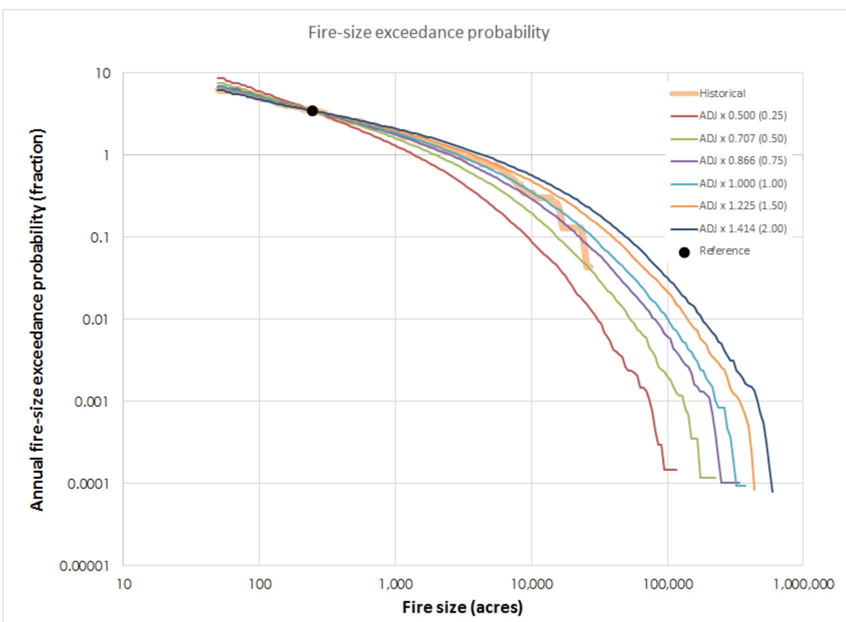
The charts below show the effect of those modified ADJ values on large-fire size (and the fire-size distribution) and number of large fires. Note that as the ADJ values vary, there is a reasonably predictable effect on large-fire size and number.



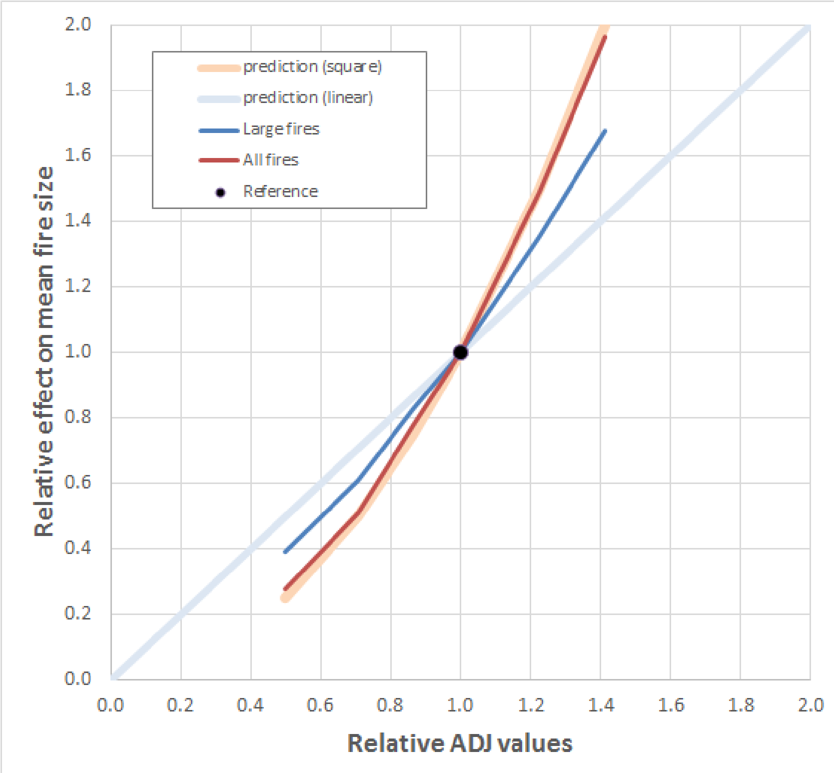
We also plotted the fire-size distributions for the range of ADJ values to see how the shape of the distribution changed. This next graph shows the effect of varying ADJ on the number of fires reaching the large-fire threshold.



We made a similar chart but adjusted the simulated fire-size distributions to reflect identical large-fire exceedance probabilities (as could be accomplished using techniques for calibrating the number of large fires[85]). Here we see that the shapes are actually similar, but their tilt (slope) varies.



Finally, we wanted to see how well our predicted change in mean fire size (the square of the ADJ adjustment) compared to the outcomes. We see that the mean large-fire size varied more than linearly but not quite with the square of the ADJ. However, by also plotting results for the mean all-fire size, we see that indeed the results do follow the prediction quite well when we don't change the distribution by truncating the fires that don't reach the large-fire size.



Nevertheless, we need to calibrate large-fire size, not all-fire size, so we'll have to keep in mind that making a universal relative change in ADJ values across all fuel models will not quite change large-fire size with the square of that relative change. But it should definitely change fire size and area burned more than linearly.

7.3.2 Using the suppression module

FSim's suppression module provides an opportunity for calibrating large-fire size. The direction of change of fire-size is predictable, but the magnitude is not. There are two settings for the suppression module. The first is whether to enable the suppression function, and the second, assuming it is enabled, is the SuppressionFactor value (also known as the trimming factor) to use.

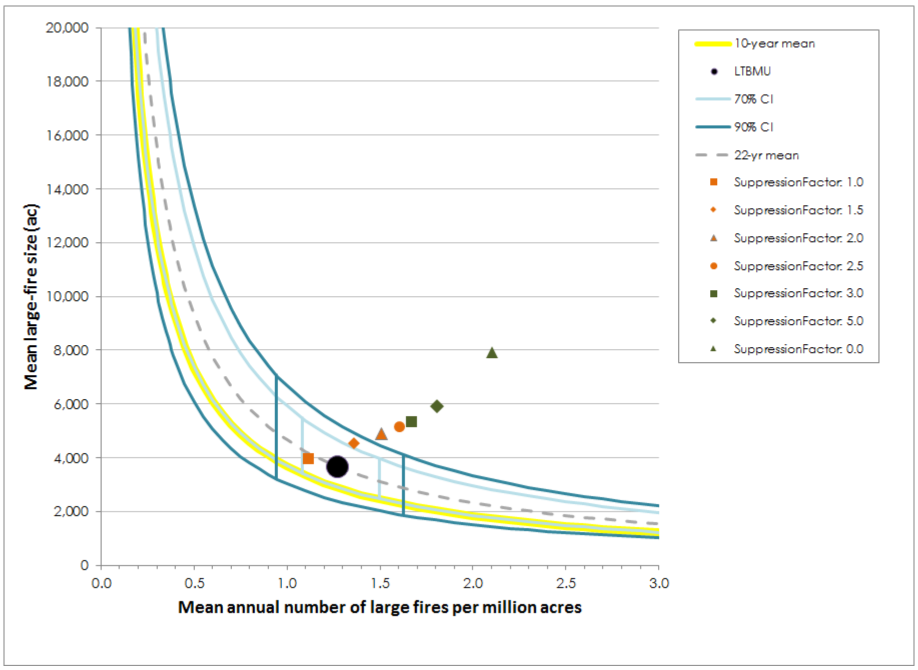
For most FSim simulations, enabling the suppression algorithm is required, at least for calibration to the historical large-fire occurrence. Reasonable values for SuppressionFactor range from about 1.0 (strong trimming) to 10 (weak trimming), and on to 0 (no trimming). Stronger trimming factors are used where suppression is typically heavy-handed (lots of firefighting resources are available, the fires are accessible, and there is little management of unplanned ignitions for resource benefit.). Weaker trimming factors are used where suppression is less heavy-handed (fewer available firefighting resources, less-accessible fires, more management of wildfires for resource benefit). Moreover, stronger trimming factors were found in the historical record in the NE part of the U.S. (SuppressionFactor ~0.9) and weaker in the Western U.S. (SuppressionFactor ~2.4).

Beyond the broad guidance above, using the SuppressionFactor for calibration is a matter of cut-and-try; change the SuppressionFactor so that fire-size moves in the desired direction and then see if the effect was strong enough, too strong, or just right. The sensitivity of fire size to SuppressionFactor varies through the range of reasonable SuppressionFactor values. A unit change in SuppressionFactor at the bottom end (near a value of 1.0) has a much greater effect than if it were at the middle or upper end of the range.

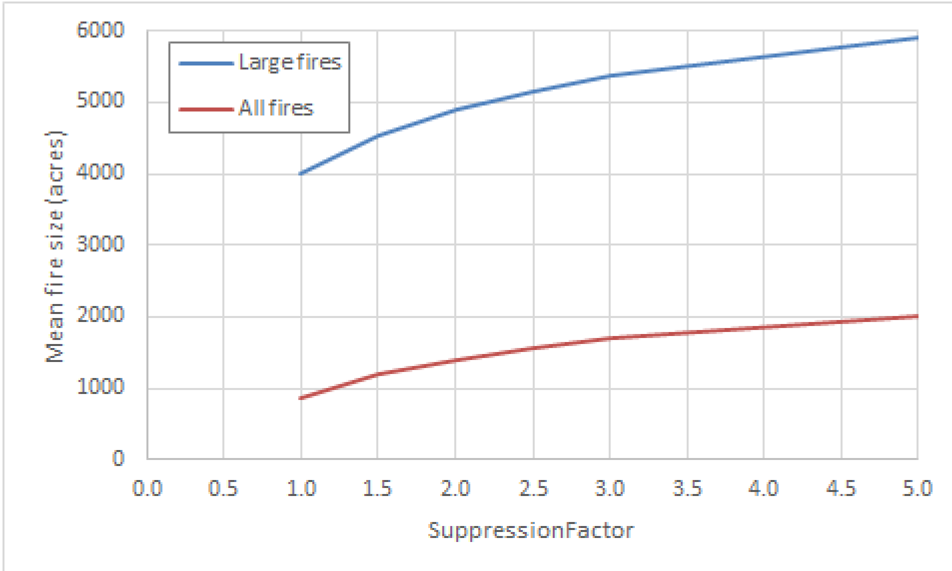
To illustrate the effects of SuppressionFactor on the number and sizes of large fires we set up a sensitivity analysis using Record: 0 (replay start locations and weather) to isolate the effects of the SuppressionFactor. Starting from final LTBMU 180-m simulation, which used a SuppressionFactor of 1.5, we made a set of seven additional simulations with a range of SuppressionFactors, as follows:

- SuppressionFactor: 0.0
- SuppressionFactor: 10
- SuppressionFactor: 5.0
- SuppressionFactor: 3.0
- SuppressionFactor: 2.5
- SuppressionFactor: 2.0
- SuppressionFactor: 1.5
- SuppressionFactor: 1.0

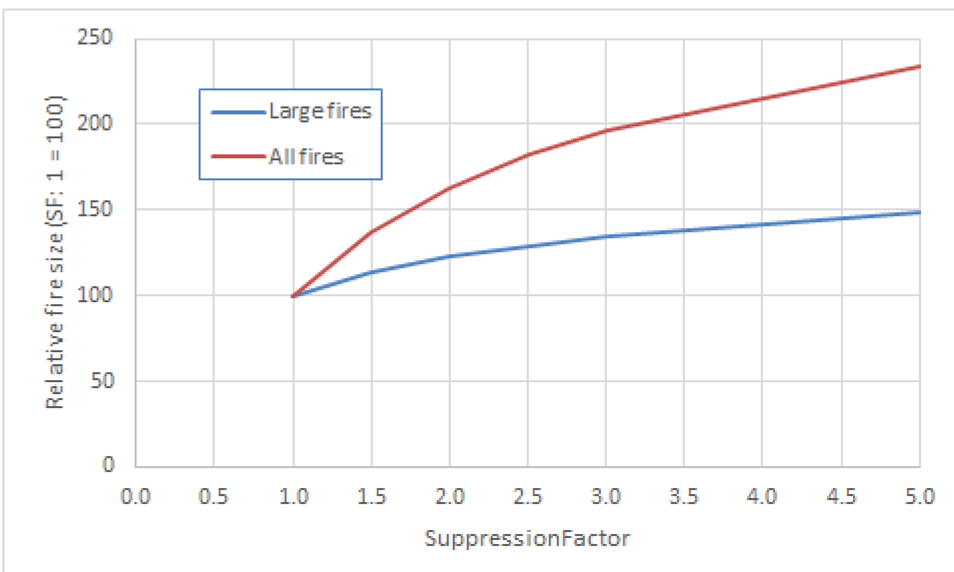
The chart below shows the effect of those new SuppressionFactor values on mean large-fire size and mean annual number of large fires. Note that as SuppressionFactor is varied through this range, the mean large-fire size and mean annual number of large fires changes predictably. The effect of SuppressionFactor seems to have a relatively strong effect on the number of fires reaching the large-fire threshold, but a milder effect on the mean large-fire size.



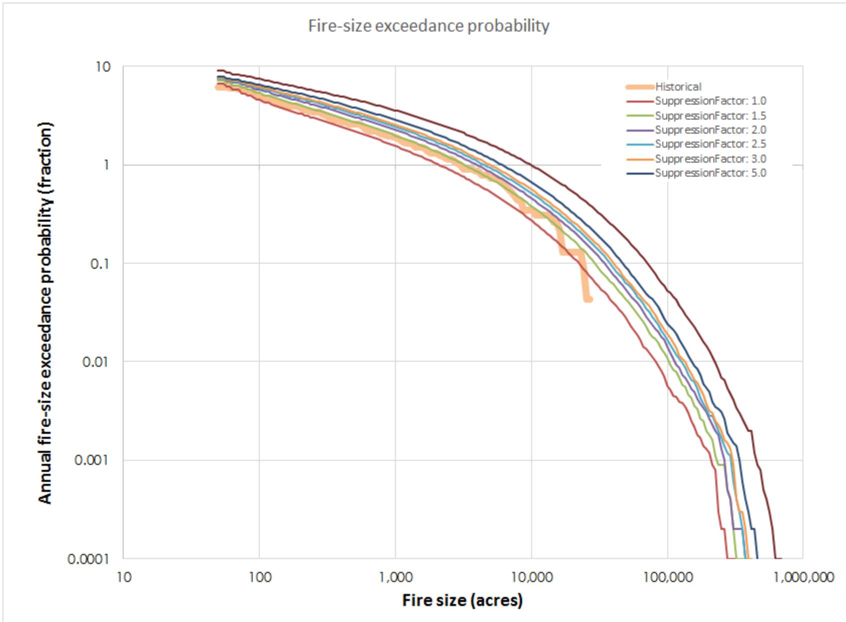
In the following chart we see that SuppressionFactor affected both the mean large-fire size and the mean all-fire size.



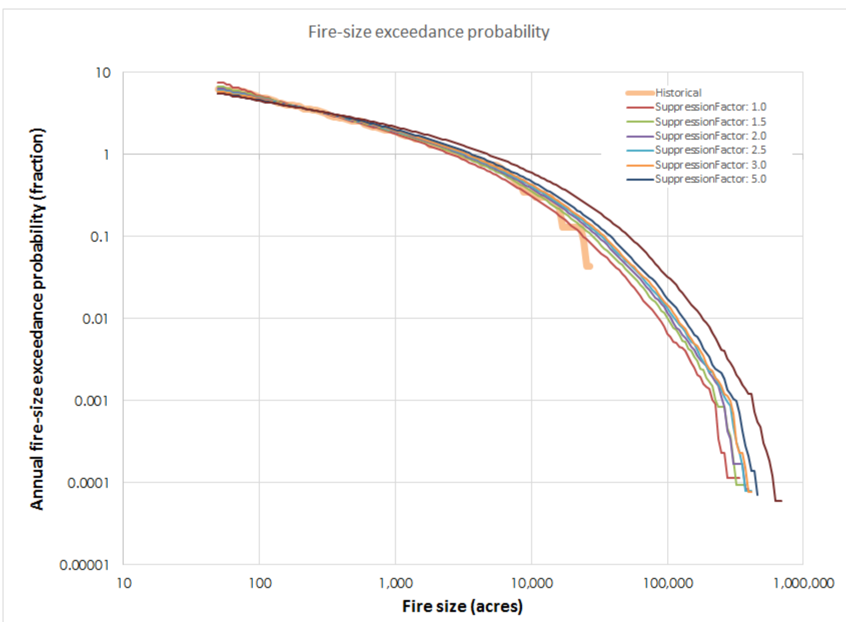
Although the shape of the two curves in the above chart appear similar, we plotted their fire sizes relative to a reference point for SuppressionFactor: 1.0 and can see that this input has a larger effect on the all-fires distribution than the large-fire distribution. This does not necessarily mean that the trimming function operates differently on fires of different sizes--it may simply be a function of the changing number of large fires for each value of SuppressionFactor.



The above graphs relate to the mean size of simulated fires. We also plotted the fire-size distributions for each SuppressionFactor value to see how the shape of the distribution changed. This graph below shows the effect of SuppressionFactor on the probability of fires exceeding the large-fire threshold.



We made a similar chart but adjusted the fire-size distribution to reflect identical large-fire exceedance probabilities (as could be accomplished using techniques for calibrating the number of large fires). Here we see that the shapes are actually similar, but their tilt (slope) varies.



7.3.3 Using the .lcp file

In most cases, the combination of ROS adjustment factor values by fuel model and SuppressionFactor are sufficient to calibrate large-fire size. Sometimes, however, it may be necessary to edit the fire modeling landscape itself. A fire modeling landscape edit is typically only needed when the current fire modeling landscape produces spread rates too low to produce the desired fire sizes or the intensity is too high. High spread rates can usually be addressed with the ROS adjustment factors. Those ROS adjustment factors adjust only the rate of spread, not the resulting intensity. So, an area that is mapped as SH7, for example, can be slowed down with an ADJ to produce fire sizes consistent with the historical record, but the high-intensity associated with SH7 will still be present. Editing the fire modeling landscape to change SH7 in a targeted area to a more appropriate fuel model could alleviate both fire size and intensity issues.

Many wildfire analysts now primarily gain much of their fire modeling experience working in the Wildland Fire Decision Support System (WFDSS). In WFDSS, an analyst may spend considerable time making fire modeling landscape edits during calibration, especially when using the stochastic model FSPro. FSPro is analogous to FSim but simulates one fire over one to several weeks, whereas FSim simulates a whole year of fires. However, the edits made in WFDSS may not be useful or appropriate for FSim, for a number of reasons:

- WFDSS models do not use rate of spread adjustment factors
- WFDSS models do not use a containment algorithm that limits the overall duration of a simulated fire
- WFDSS models do not use a perimeter trimming algorithm that simulates progressive fireline construction

Because these features are not present in WFDSS, it may be necessary to make fire modeling landscape edits in WFDSS in order to limit simulated fire growth. Because these features available and commonly in FSim, those same fuel edits may not be necessary, and may even be counter-productive.

7.3.4 Using the .fms files

Surface fuel moisture content can influence surface and crown fire rate of spread and intensity. In fuel models with an herbaceous component, the live herbaceous moisture content is a critical parameter affecting predicted fire behavior. This value can be adjusted for specific fuel models. For fuel models consisting of primarily dead fuel, the moisture content of the 1-hr timelag class is the most important parameter affecting predicted fire behavior. Adjustments to the live and dead surface fuel moisture inputs can be made to specific fuel models in the FMS files for each range of ERC-G values.

Global adjustments of fuel moisture content values--or targeted adjustments to specific fuel models--can be used to calibrate large-fire sizes, but not in a highly predictable way. Moreover, the effect of changes to fuel moisture on fireline intensity may not be desirable. For example, increasing dead fuel moisture using the .fms file to slow down fire spread could cause FSim to underpredict flame length.

Using the .fms files to calibrate large-fire size should only be undertaken if those changes produce a desirable effect on fire intensity. Otherwise, it is best to use ROS adjustment factors.

7.3.5 Using the .frisk file

The .frisk file 40 contains information about weather-related inputs, including time-series data regarding the seasonal trend in ERC, ERC percentiles, and the monthly distributions of wind speed and direction. Of those only the latter two can play a role in calibration of large-fire size.

Using the .frisk file during calibration is typically limited to selecting a different RAWS for wind data, or, less often, choosing to include wind gusts in the dataset. A "windier" RAWS will produce larger fires, and more of the fires will reach the large-fire threshold. Including wind gusts rather than only 10-minute average winds will have the same effect. In both cases, it is hard to predict the magnitude of the change in large-fire size, so it is a matter of using a different wind speed dataset and then judging the result on large-fire occurrence and size.

7.3.6 Using the fire-size limit

The FireSizeLimit simulation parameter exists to prevent FSim from simulating ridiculously large fires that the fire environment may not really be capable of supporting. It is best to begin simulations with no upper limit on large-fire size. From this simulation it is easy to determine the effect a smaller FireSizeLimit would have by summing the number and size of fires greater than the large-fire threshold but less than a hypothetical FireSizeLimit. Reducing the FireSizeLimit typically reduces the number of large fires by a small amount (because very few fires become so large) but can reduce the mean large-fire size by a more significant amount.

The advent of the perimeter trimming algorithm has obviated the need for the fire-size limit, as few if any ridiculously large fires are generated with perimeter trimming enabled. It is best practice to avoid using this switch and instead use other factors to control area burned. During calibration, it is easy to see what the effect on the fire-size distribution and mean large-fire size would be if this switch were set to various values. However, if it is to be used, it is important not to use a FireSizeLimit that is too small, as the real potential for large fires to occur on the landscape may then be under-predicted.

NOTE: Do not use a fire-size limit on a replayed simulation (Record: 0), as that can eliminate fires that you actually want to remain in the results.

7.4 Calibrating large-fire number

Before we talk about how to calibrate the number of large fires, let's first talk about why we need to do it. Out of the box, an FSim simulation will not produce enough large fires. There are two main reasons for this. First, FSim only ignites fires when the ERC is at or above the 80th percentile, whereas some fraction of historical large fires could have started at ERC values lower than that. Those fires are "missing" from the simulation. Second, not all of FSim's simulated fires reach the large-fire threshold used to generate the calibration target. In fact, it is common that as few as 20-50% of the fires ignited in FSim reach the large-fire size threshold, especially if perimeter trimming is enabled. Those small fires are also "missing" from the simulation because FSim doesn't know they didn't reach the size threshold and can't simply replace them. The calibration process "replaces" these missing large fires.

Calibrating the annual number of large fires is relatively straightforward compared to the calibration of large-fire size. In fact, if the large-fire size distribution is to remain unchanged between two successive runs, it is straightforward to attain any desired annual number of large fires using a number of techniques. The alternatives include:

- Generating an entirely new .fdist file in FFPlus using a different large-fire size threshold
- Adjusting AcreFract in the current .fdist file
- Adjusting the fire distribution table in the current .fdist file
- Adjusting both the AcreFract and the fire distribution table in the current .fdist file

These first two techniques are detailed in the following sections. The latter two techniques not included because they are used by few analysts, and similar results can be achieved using the first two techniques.

7.4.1 Use different fire-size threshold

We present this technique first because it is used by a number of analysts. It is imprecise compared to other techniques, but can be combined with them if increased precision is needed.

Recall that generating the .fdist file[43] requires first setting the large-fire size threshold. The .fdist file contains two sections that relate to this large-fire size threshold. First, it lists logistic regression coefficients used to calculate the probability that a day will experience at least one fire that exceeds that size (based on ERC). Second, it has a table that lists the number of large fires discovered on each day that at least one large fire was discovered, again using the same large-fire size threshold.

Let's say that we need to double the number of simulated large fires in order to meet the historical target. You can attempt this by building a new .fdist file based on a smaller large-fire size threshold. In fact, to double the number of fires, use a large-fire size threshold for which the number of historical fires greater than this new threshold is about twice that of the nominal threshold. When you generate a new .fdist, the new combination of logistic regression coefficients and fire-day distribution table will result in roughly double the number of simulated fires. However, the exact amount of that increase is unpredictable, so it's a matter of cut-and-try.

If you think you may want to use this approach during calibration, generate a set of .fdist files for various fire-size thresholds smaller than the nominal size so they are readily available during calibration.

In most cases, changing only the fire-size threshold used for the .fdist does not significantly affect the simulated large-fire size distribution.

Remember that even though you are using a .fdist generated for a smaller-than-nominal large-fire threshold, you still compare the simulated and historical number and sizes of fires based on the nominal large-fire size threshold.

7.4.2 AcreFract

The AcreFract setting in the .fdist file[43] is a holdover from the days before a national all-lands fire occurrence database (Short 2015) was available. Back then, it was common to have complete fire-occurrence data for only a portion of the overall landscape. For example, there might have been data for federal land only, but not for private land within the landscape. AcreFract represented the fraction of the landscape for which there was fire occurrence data used to build the .fdist file. Let's say that you had fire-occurrence data for half of the landscape, and you built your .fdist from that dataset. AcreFract would then be 0.50. FSim uses AcreFract to modify the probability of a large-fire day. AcreFract is a divisor on the probability of a large fire day. An AcreFract of 0.5 therefore doubles probability of a large-fire day. All other things being equal, this will double the number of simulated fires, which was needed to correctly cover the landscape.

Most custom FSim runs now have fire-occurrence data for the entire fire modeling landscape, and therefore use an AcreFract of 1.0. Sometimes an FSim run is done for a small portion of a much larger FOA. In those cases the Default AcreFract is greater than 1.0. But watch out, the Fire distribution table in such a case assumes that multiple-fire days occur on the large landscape, and FSim will apply them to a smaller landscape. That could lead to significant overburn.

We can use the math behind AcreFract to adjust the number of simulated fires, even though it is for a different reason. If an AcreFract = 1.0 simulation produces too few large-fires by a factor of three, then we need an AcreFract of 1/3 = 0.33 to produce triple the current number of simulated large fires (all other inputs being equal).

Note that this approach works as calculated only until the AcreFract-adjusted probability of a large-fire day approaches 100% for ERC values that can occur within the simulation. The ERC value at which this happens depends on the size of the FOA and the historical occurrence rate within it, but is typically at or below an AcreFract of 0.15. Once this limit is reached, the AcreFract approach to calibrating the number of large fires must be combined with another technique.

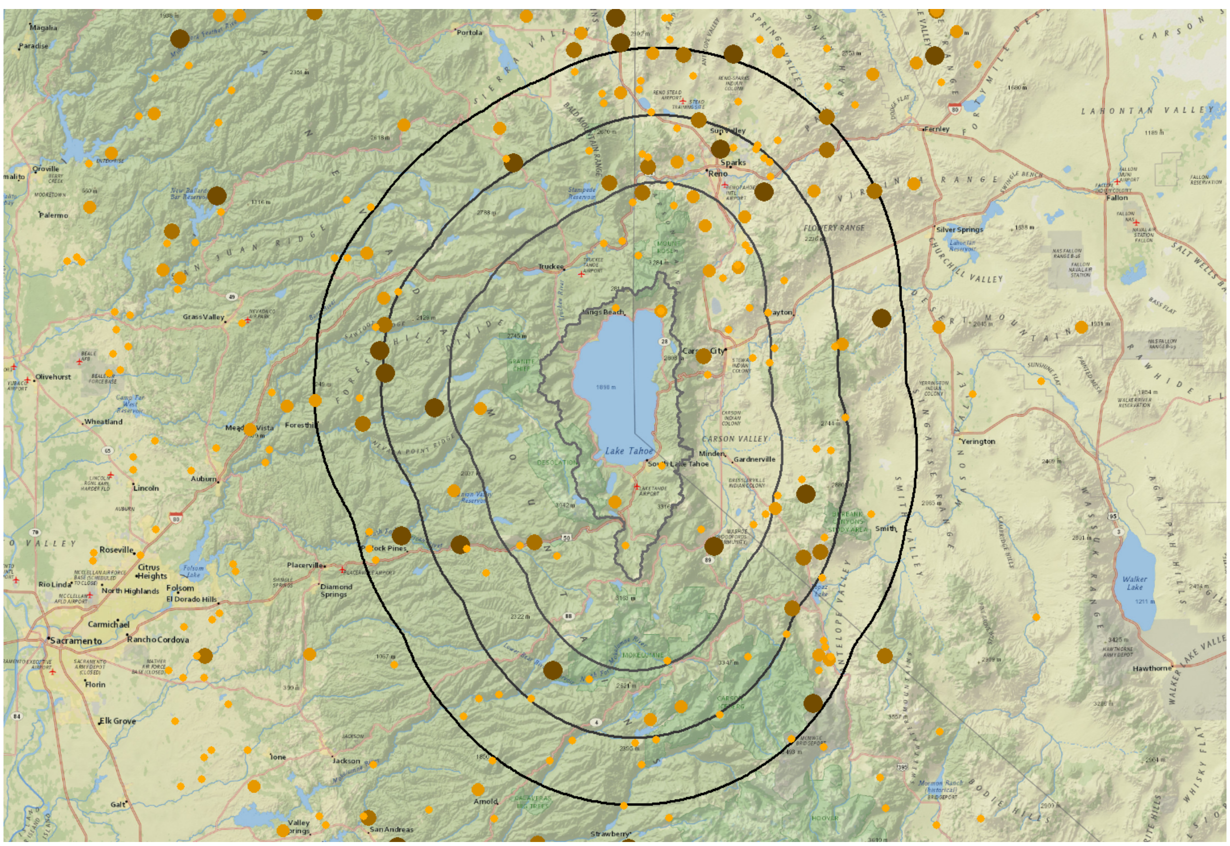
7.5 LTBMU example

The LTBMU calibration example is incomplete, but nonetheless provides an example FSim calibration. This section shows some of the spatial data used to generate spatial and tabular FSim inputs. The Setting the Zones 62 topic has further information about the LTBMU FSim project.

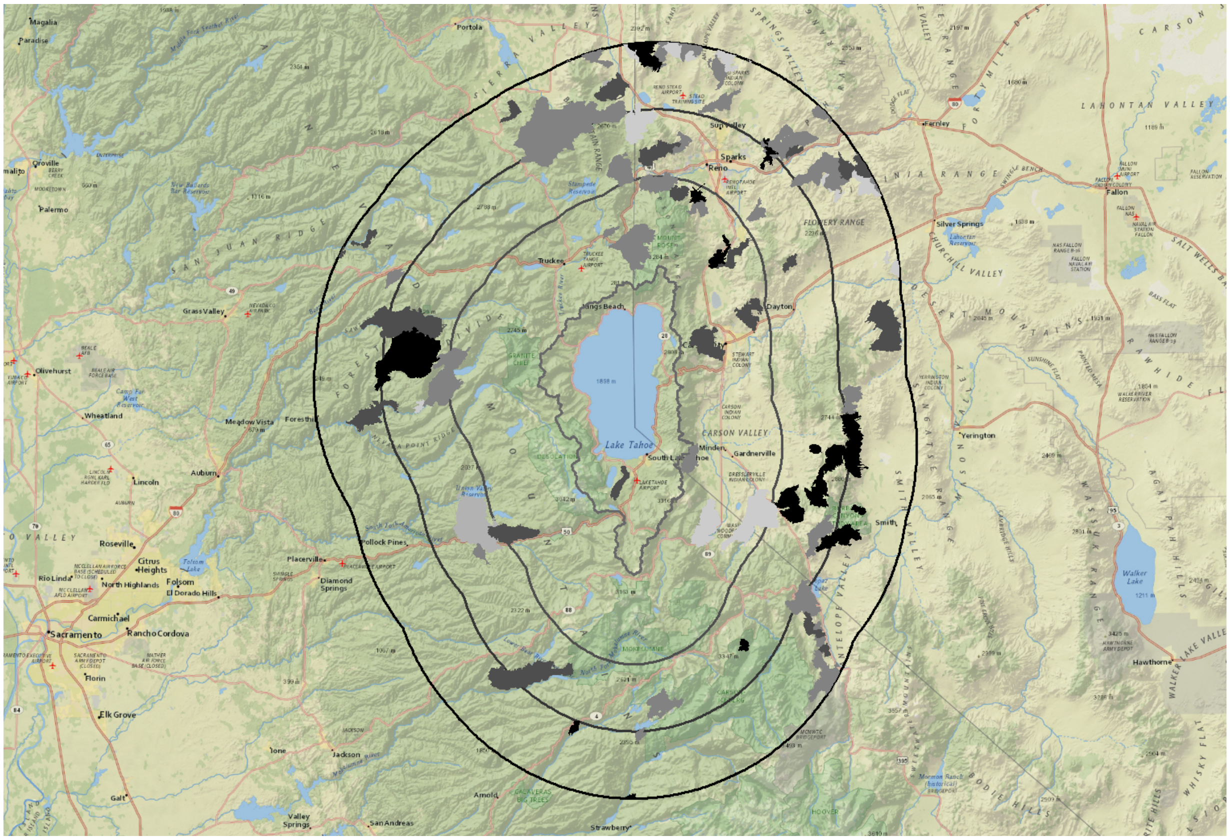
The image below shows the locations of large-fire ignitions over the historical period. In this example, a large fire is one over 100 ha (247.1 ac) in size. The polygons shown in the image represent the landscape zones 62 from inside to outside:

- Land Management Unit
- Analysis Area
- Fire Occurrence Area
- Fire modeling landscape area

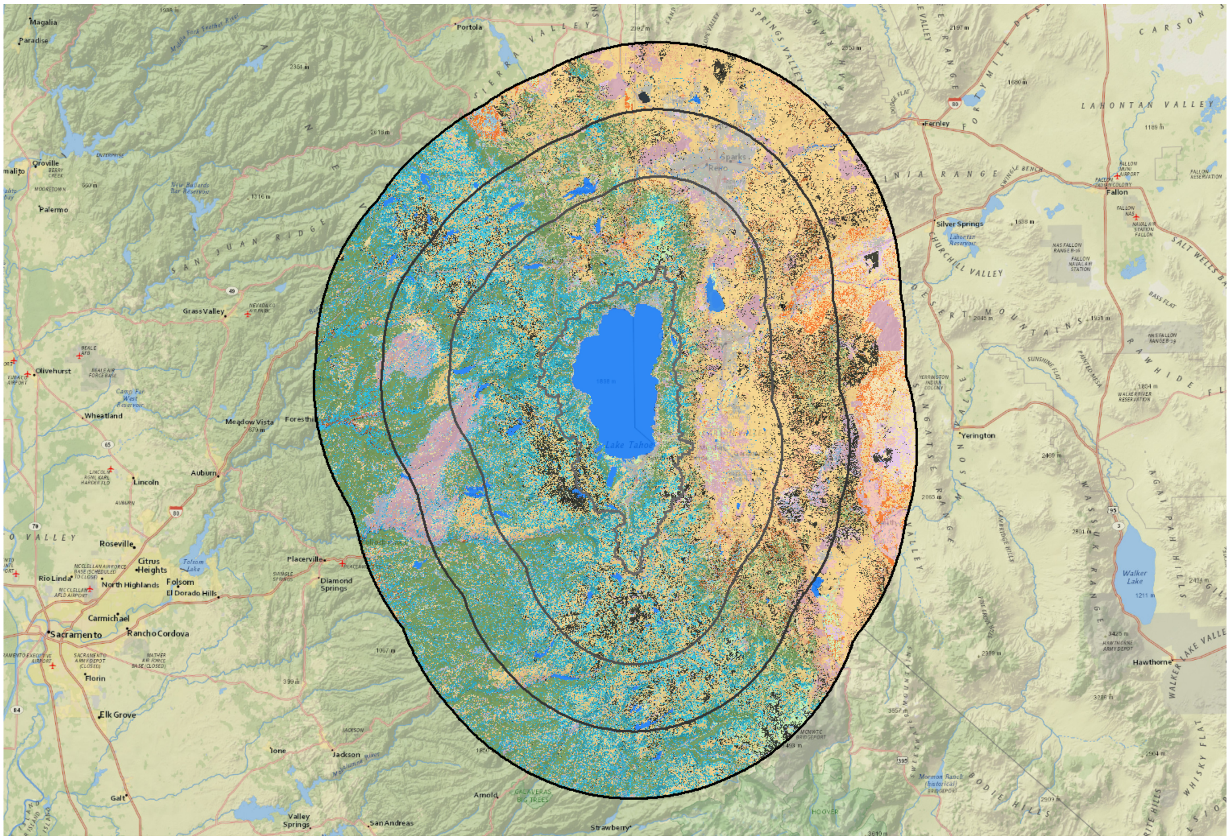
We show fires outside of the LCP area because those are necessary to produce the Ignition Density Grid.



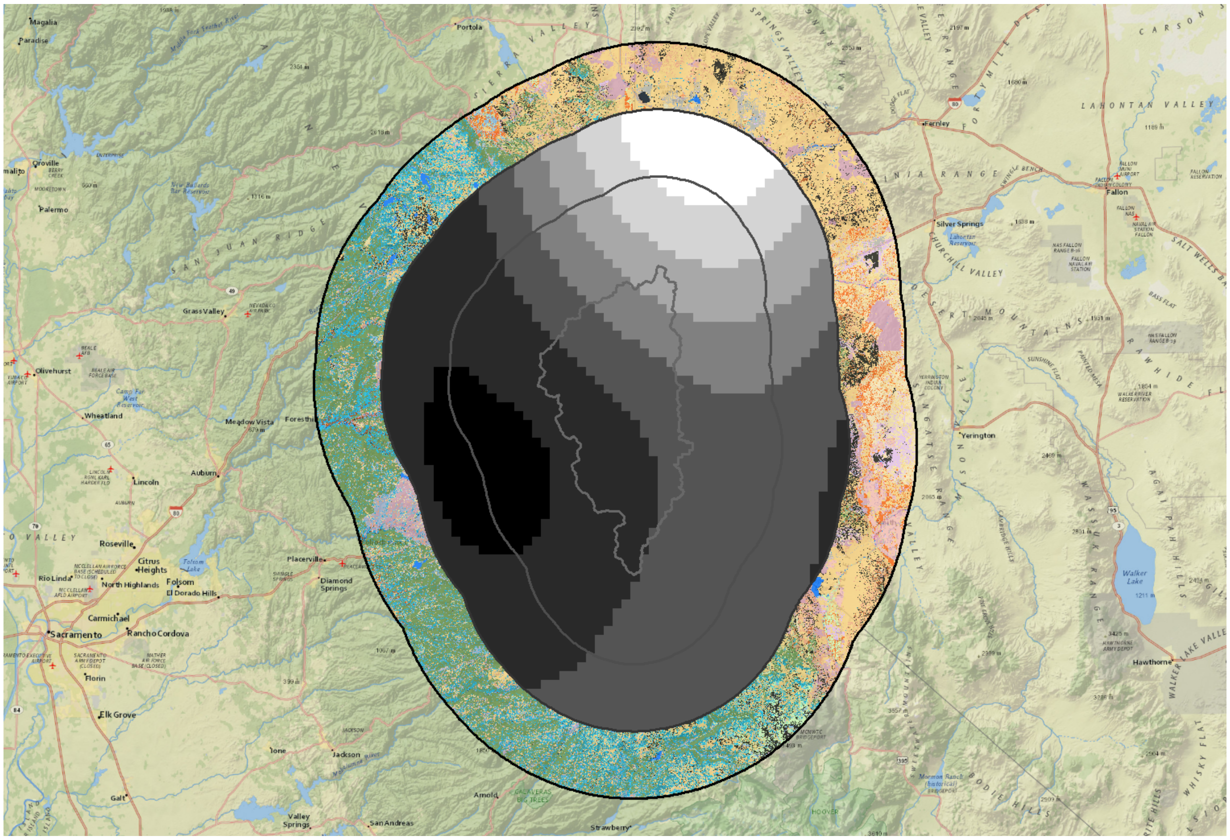
The image below shows the land areas burned in wildfires over the same historical period above. Darker polygons are more recent fires. These data are from the Monitoring Trends in Burn Severity (MTBS) project.



This image shows the surface fire behavior fuel model data for the fire modeling landscape extent. It is not necessary to have data outside this extent, and having additional landscape data leads to longer run times.

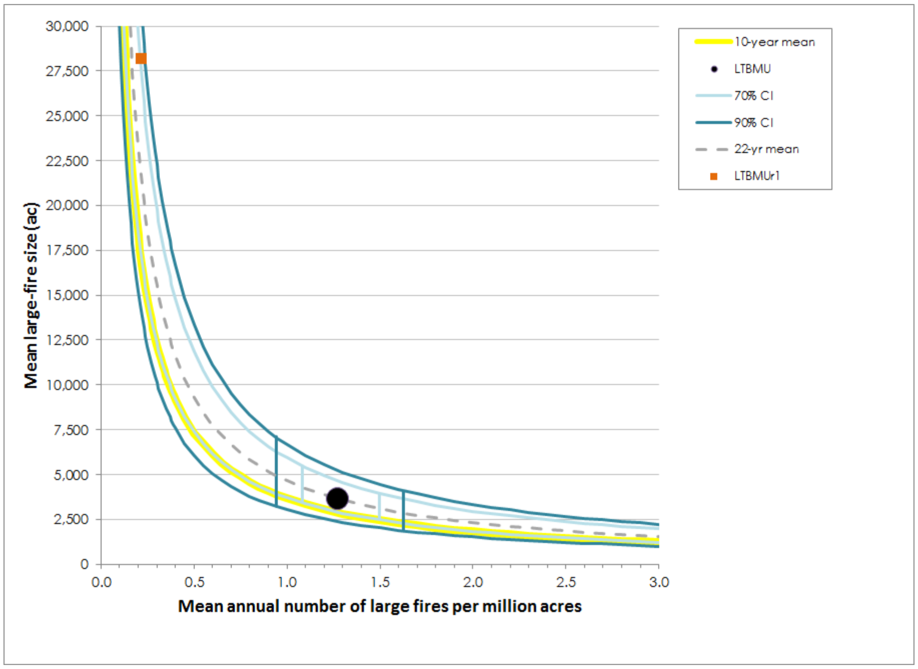


The image below shows the final ignition density grid used for the project. The IDG itself covers an area larger than the fuelscape, but zero values are shown as transparent to illustrate that we zeroed out the IDG outside of the Fire Occurrence Area extent. This means that FSim will not locate fire ignitions outside of the FOA extent, which is consistent with our parameterization of FSim inputs. Here, lighter colors indicate a higher density of historical ignitions.



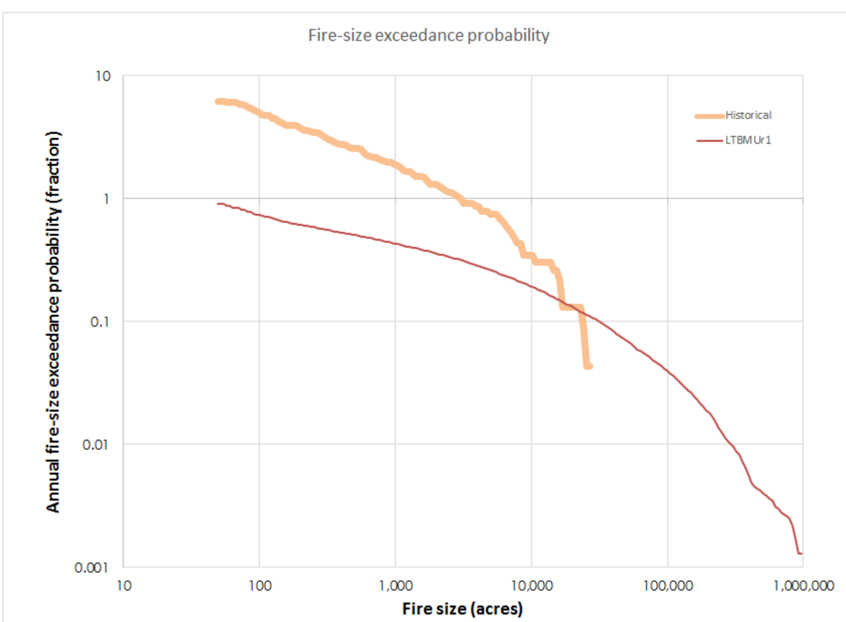
7.5.1 LTBMU Run 1

We established Run 1 with baseline inputs for everything, including ROS adjustment factors = 1.0 for all fuel models and AcreFract = 1.0. We enabled the suppression module and used a SuppressionFactor of 2.0. A 10,000 iteration, 180-m simulation with these baseline inputs produced the following result.



The Run 1 result ended up in the extreme upper-left hand corner, with fire sizes that are too high by a factor of nearly eight (mean large-fire size was 28,224 acres compared to the historical mean of 3,659 acres). Also, the number of large fires was too low by a factor of nearly six (the simulated mean annual occurrence rate was 0.215 large fires per million acres per year compared to the historical mean of 1.272 large fires per million acres per year). On balance, those two factors somewhat offset each other, producing a mean annual area burned that was only 30% higher than historical.

Despite the similarity of acres burned, the difference in the composition of those acres burned--too few fires, getting too large--is highlighted by the fire-size exceedance probability chart below. We really want to match the simulated curve to match the historical much better than that.

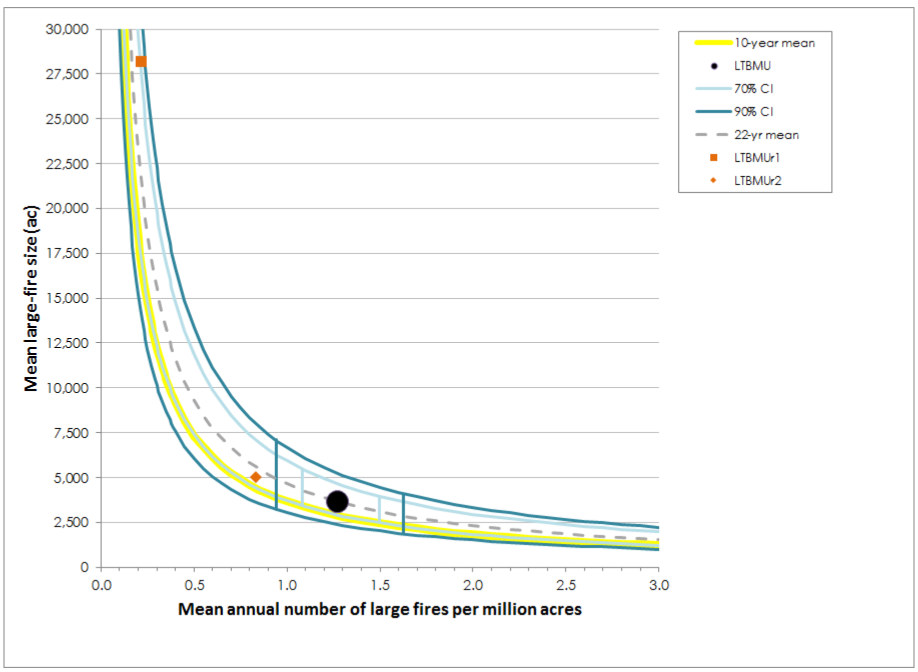


7.5.2 LTBMU Run 2

For Run 2 we wanted to get the mean large-fire size back down to reality. Recall that the Run 1 large fires were too large by a factor of 7.71. In this section[77] we talked about estimating a universal change in ADJ value to accomplish a specific adjustment such as this. The estimate is SQRT(1/7.71) = 0.36. We set up Run 2 with ROS adjustment factor values of 0.35 (a nice round number near our calculation) for all fuel models.

To illustrate the futility of trying to calibrate the number of large fires while still calibrating their sizes, we decided to make a calculated attempt to do so. Run 1 produced too-few fires by a factor of 5.9, so an AcreFract of 1/5.9, or 0.17, should produce close to the desired number of large fires (assuming the large-fire fraction does not change).

So, Run 2 had two changes: ROS adjustment factors of 0.35 for all fuel models and AcreFract of 0.17. A 10,000 iteration, 180-m simulation produced the following result.

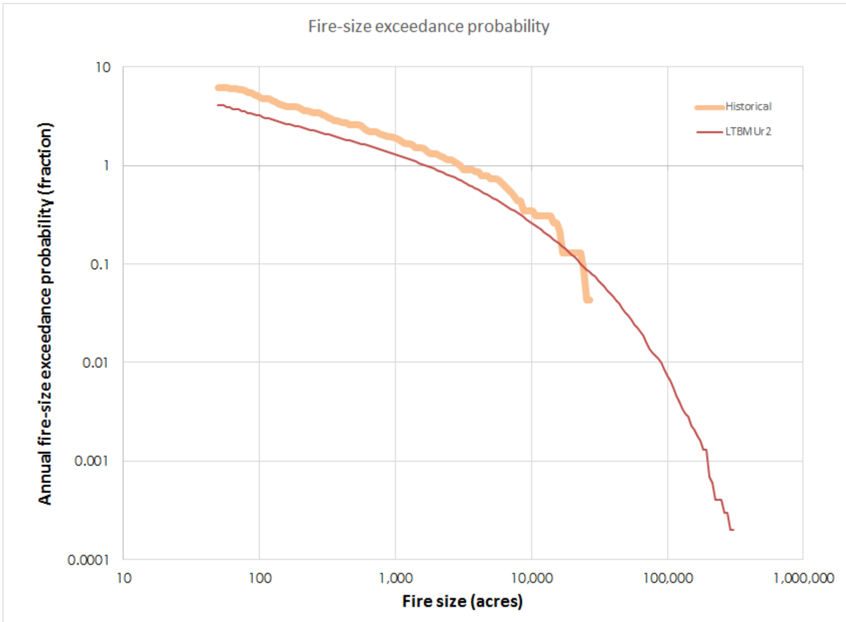


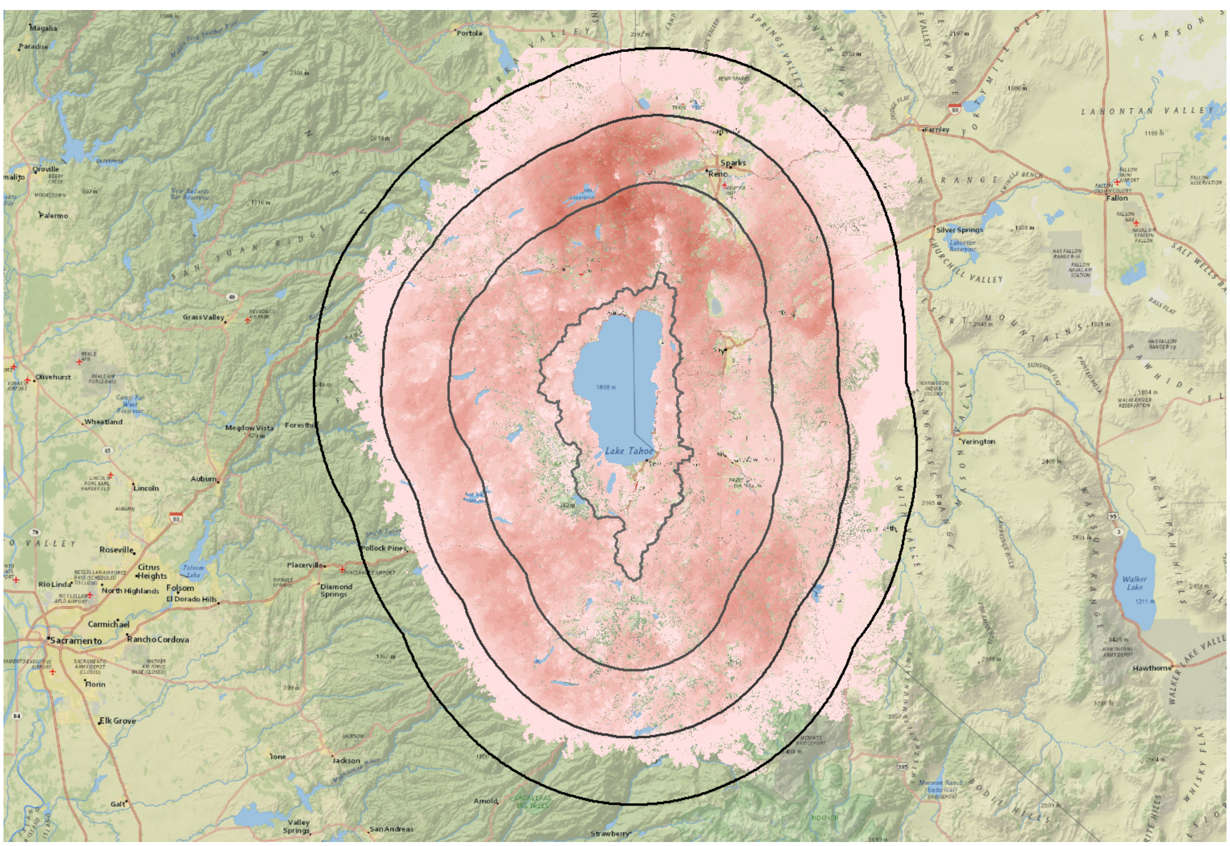
Ok, now we're getting somewhere. The ADJ edit brought fire sizes down to nearly the target value, and the number of large fires increased, but is still well short of the goal.

Why did the fire size not come down all the way? Well, there could be any number of reasons, including stochasticity (there is a much larger sample size of fires in Run 2 than Run 1). But one possibility is that the fires from Run 1 were so large that a great many of them were truncated by the edge of the .lcp file, biasing the mean large-fire size calculation.

Why is the number of large fires still so far from the target? That's easier...because the ADJ edit meant that a much smaller fraction of FSim's fires reached the large-fire threshold. In Run 1, 43.4% of all ignitions reached the large-fire threshold, whereas only 28.7% did in Run 2. In fact, if this ratio had not changed between runs, Run 2 would have produced 1.25 large fires per million acres per year compared to 1.27 in the historical record. The method of changing the number of large fires works, but only once the large-fire fraction is stable.

Those two edits produce a much improved fire-size distribution, but there is still work. The shape of the distribution is pretty darn good, but it's shifted downward, indicating too few fires, which we also see from the calibration chart above.

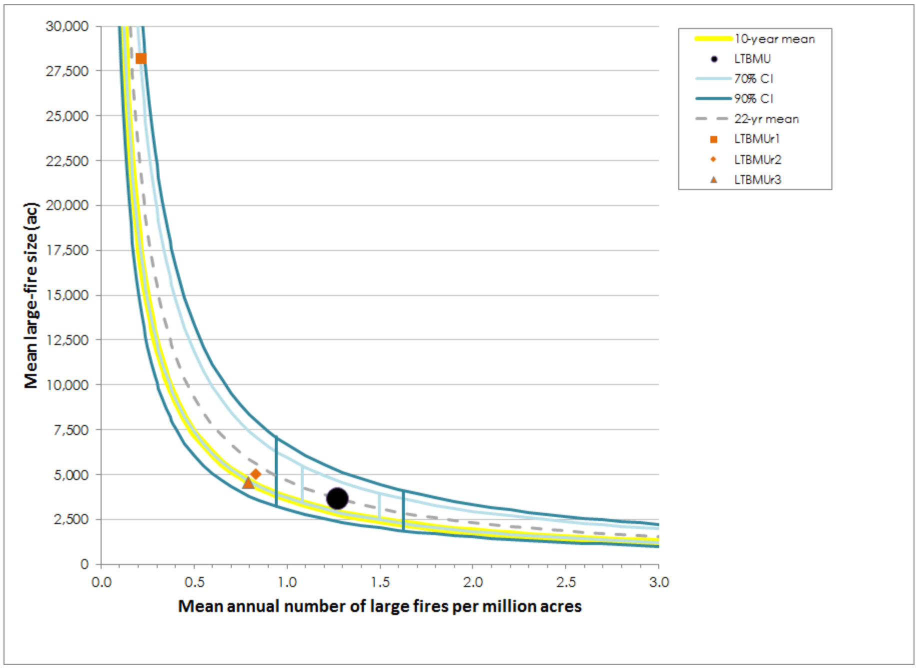




7.5.3 LTBMU Run 3

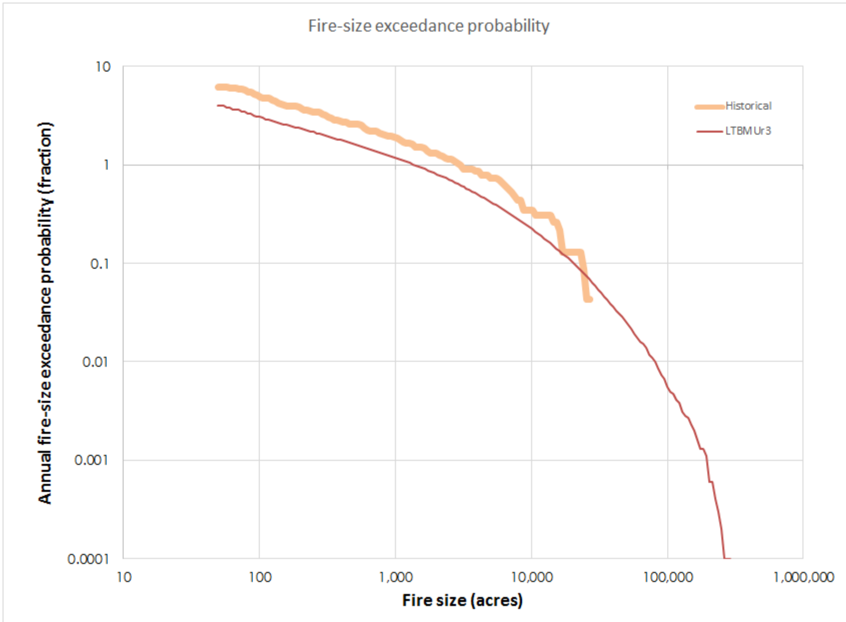
We did Runs 1 and 2 for purposes of explaining what it's like to start from scratch with ADJ values of 1.0, and then how to make a universal ADJ edit. After calibrating dozens of FOAs in great detail, we now never start calibration with ADJ values of 1.0--it simply never works. And we don't typically start with uniform ADJ values across all fuel models. Instead, we typically start calibrating with ADJ values of 0.25 for GR and GS fuel models, and 0.40 for SH, TU, TL and SB fuel models.

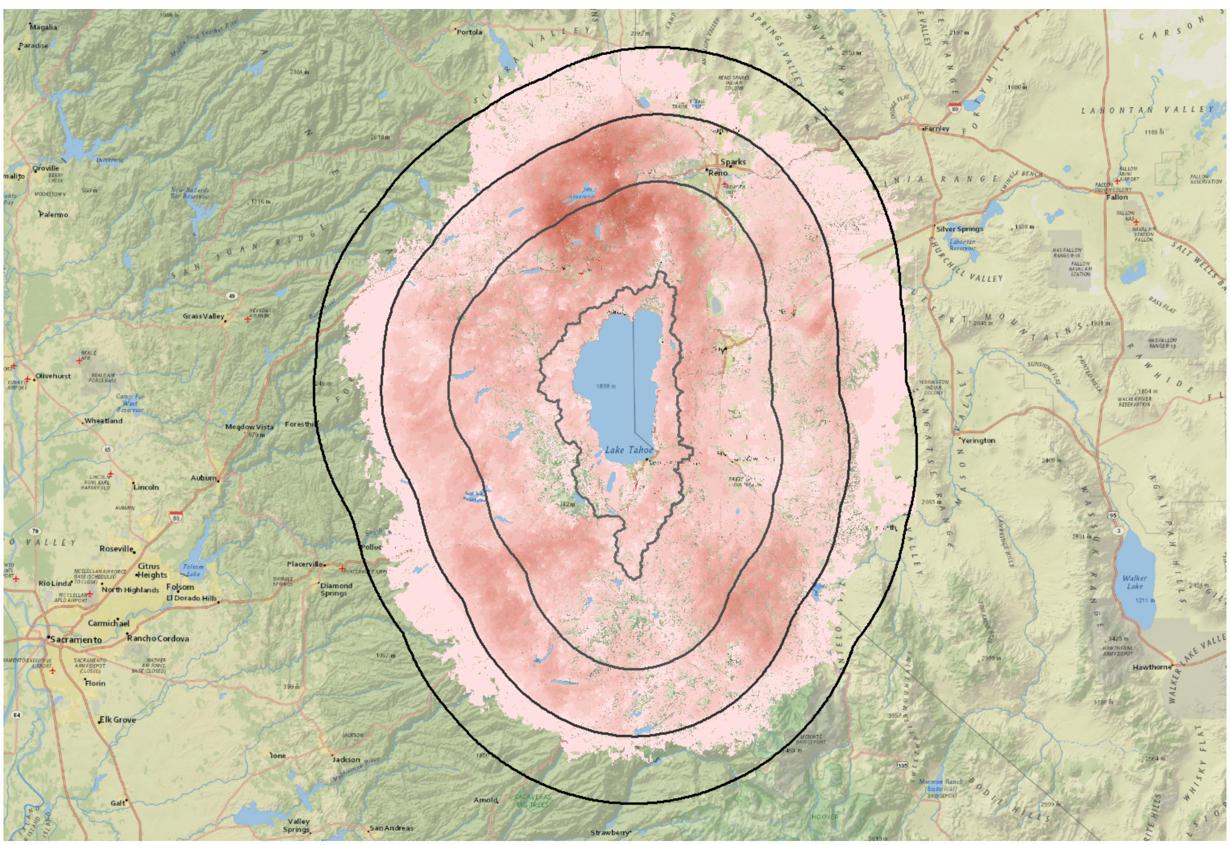
For Run 3 we used this more typical set of ADJ values along with the AcreFract adjustment calculated from Run 1 to produce the following result.



Lucked out! Our typical starting ADJ values put us in a very similar spot as Run 2. The Run 3 fires were a little smaller (closer to the historical mean), so the large-fire fraction was also smaller, resulting in slightly fewer large fires than Run 2. The shape of the Run 3 fire-size distribution still matches the historical quite well, except for the number of large fires.

All in all, Run 3 looks pretty good, and it's what we would have started with in normal circumstances, so we'll continue calibrating from that. The fire sizes look reasonable, but perhaps a tiny bit high. For Run 4 we'll make another fire-size adjustment, and another adjustment for the number of fires.





7.5.4 LTBMU Run 4

Recall that for Run 4, we wanted to make another fire-size adjustment, and another adjustment for the number of fires. The needed fire-size adjustment is small--if it's needed at all. We decided to see what setting SuppressionFactor to a tighter value would accomplish. Up to now the SuppressionFactor was 2.0, so we decided to try 1.5. Although 1.5 is tight for the western U.S., this particular landscape is home to some of the most aggressive suppression anywhere--there are a lot of firefighting resources available in short order, and they are used with little restraint. So, if a tighter SuppressionFactor is justified anywhere in the western U.S., perhaps this is the place.

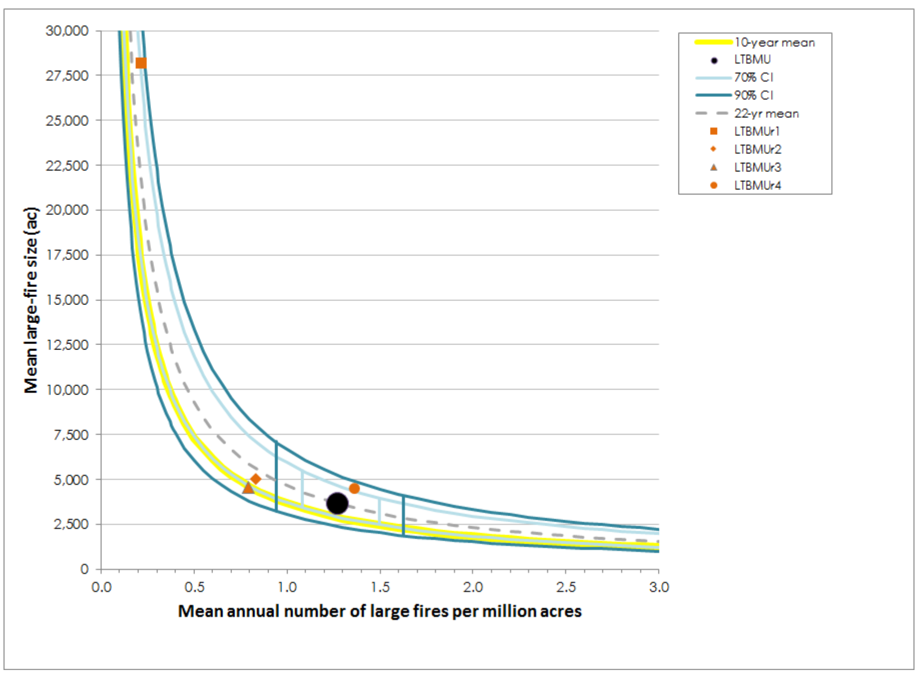
We also need to get more large fires, about 60% more than Run 3. To get 60% more fires we would need to adjust the current AcreFract (0.17) by 1/1.6, or 0.625. Multiplying 0.17 by 0.625 gives a new AcreFract of 0.106. And with our SuppressionFactor edit (2.0 to 1.5), we will likely need even more fires than that would give us. For the Run 4 .fdist file, we will try an AcreFract of 0.11 and edit the Fire-day distribution table so that we have about 1.2 times as many fires per large-fire day (see the Fire distribution topic for details). If there were no change in the large-fire fraction between Runs 3 and 4, this .fdist file edit would give us the number of fires calculated from this equation.

$$\frac{FDD_{new}}{FDD_{current}} * \frac{AcreFract_{current}}{AcreFract_{new}} = \frac{NumFires_{desired}}{NumFires_{current}}$$

For the inputs we're talking about in this case, we would expect about 1.85 times as many fires.

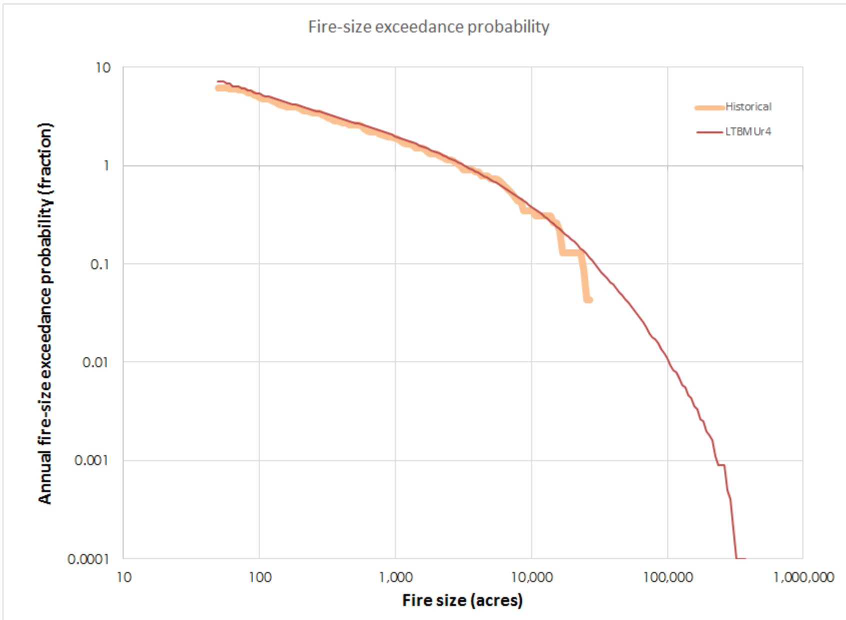
$$\frac{1.229}{1.025} * \frac{0.17}{0.11} = 1.85$$

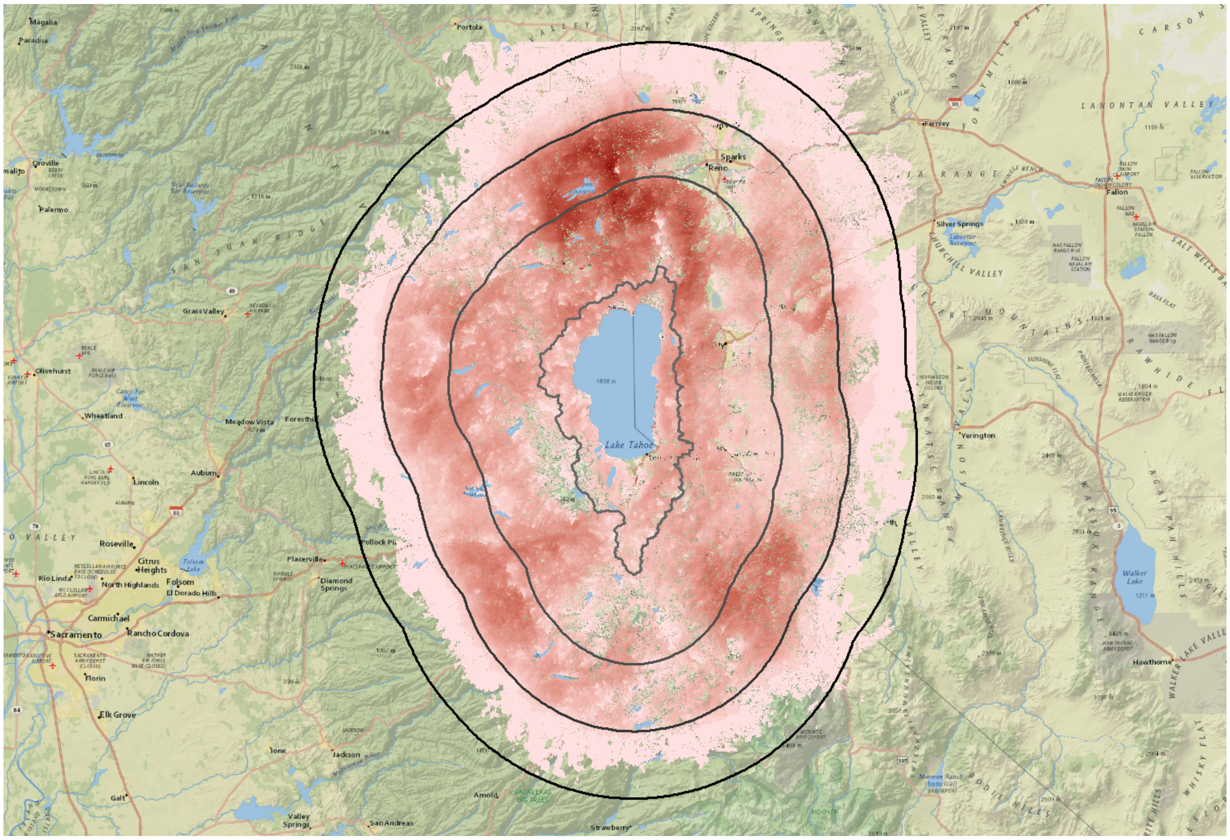
So, by shooting for 1.85 times as many fires but actually hoping for only 1.6 times as many, we're estimating that the large-fire fraction will reduce by a factor of 1.6/1.85, or 0.86. Let's see what happened.



Doh! Well, we're closer to the target now, but still a little high on fire size, and now we're high on the number of fires as well. As it turned out, the SuppressionFactor had a negligible effect on mean fire size, and a small effect on the large fire fraction, which reduced by a factor of 0.93 compared to our assumed factor of 0.86. Still, we're closer than if we had not made that extra adjustment.

Looking at the fire-size distribution, we're looking pretty great. In fact, we can see that we match the historical fire-size distribution up to fires of about 20,000 acres. The historical distribution seems to be "missing" some of those moderate-size fires between 20,000 and 100,000 acres. If anything our simulated fire-size distribution could be a better representation of the true distribution than the historical, which is based on only 23 years. It is definitely justification for leaving the mean large-fire size where it is on the high side of historical.

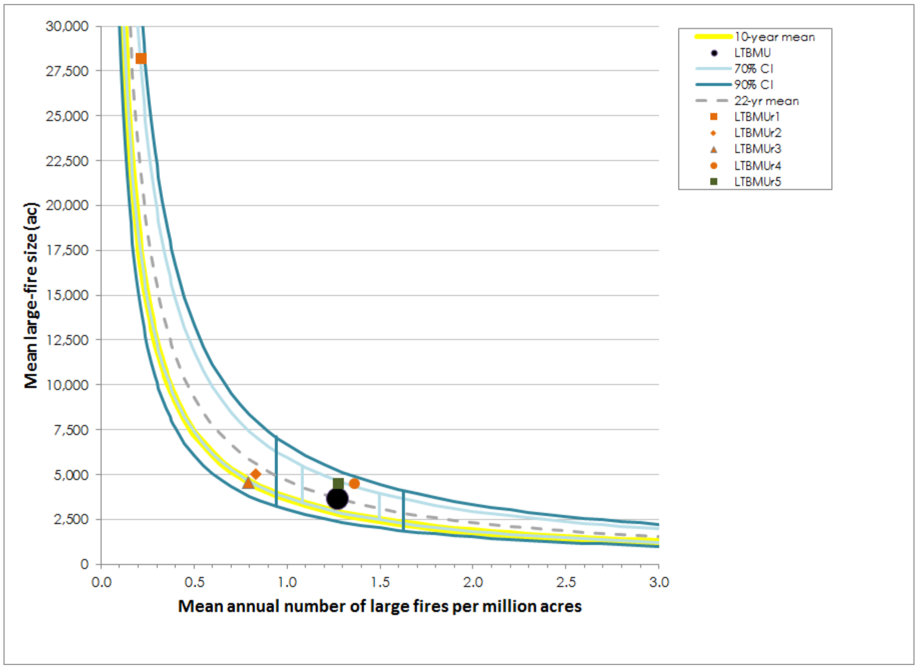




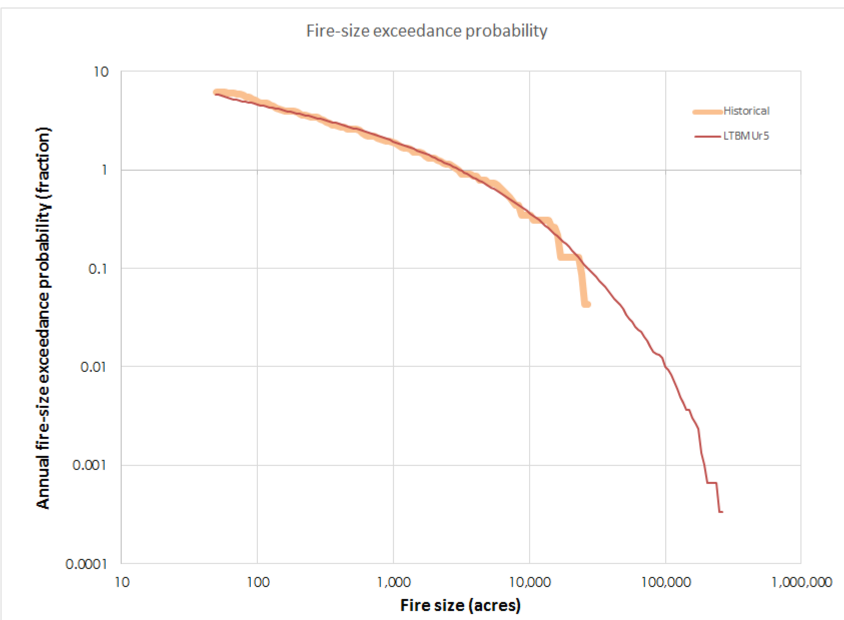
7.5.5 LTBMU Run 5

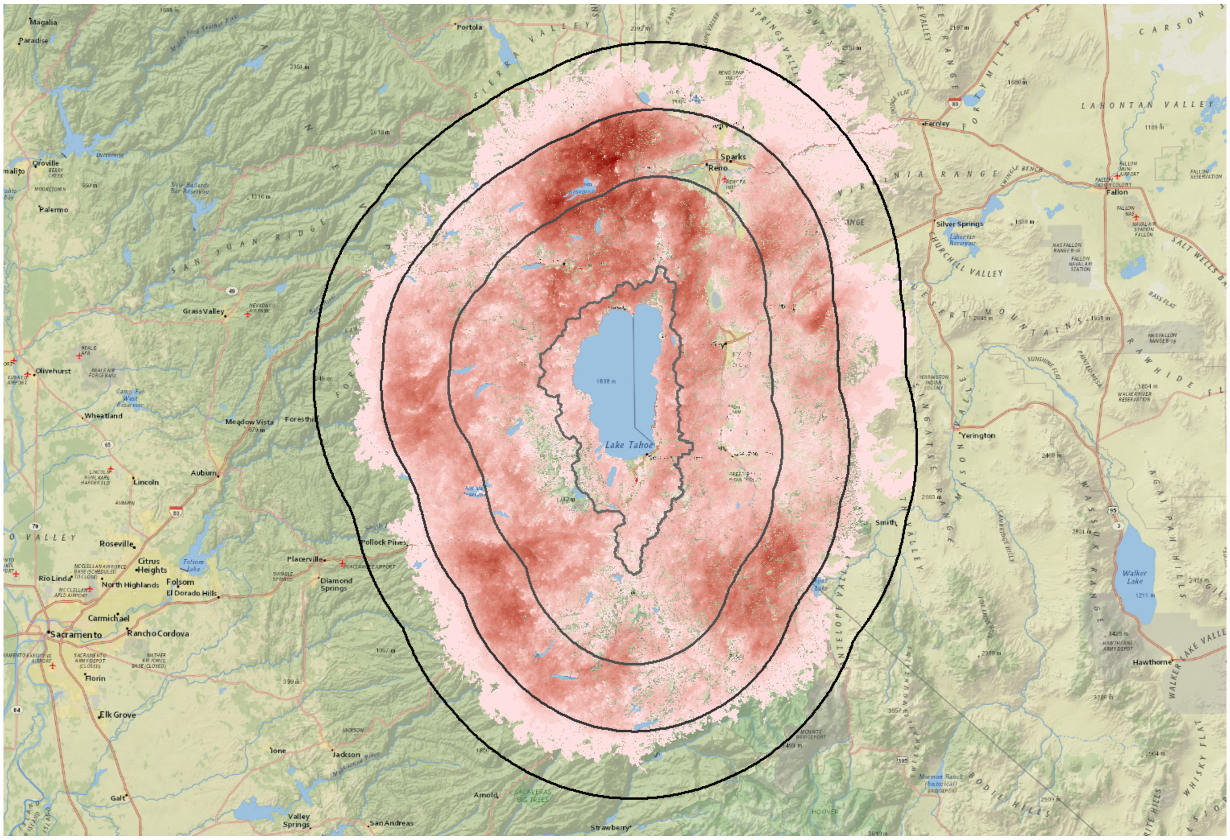
Run 4 left us in a really good spot. For a 180-m simulation it could be considered done. But we want to go to a 120-m resolution. Changing resolution can sometimes change the number of size of large fires even if the same inputs are used in both simulations. Because a 120-m resolution simulation takes so much longer to run than a 180-m run, it is reasonable practice to do a lower-iteration test run to first see if we'll need an adjustment of fire size or fire number before committing to a full 10,000 iteration run.

So, Run 5 uses the same inputs as Run 4, but with a 120-m .lcp file, a Resolution setting of 120-m, and 3,000 iterations.



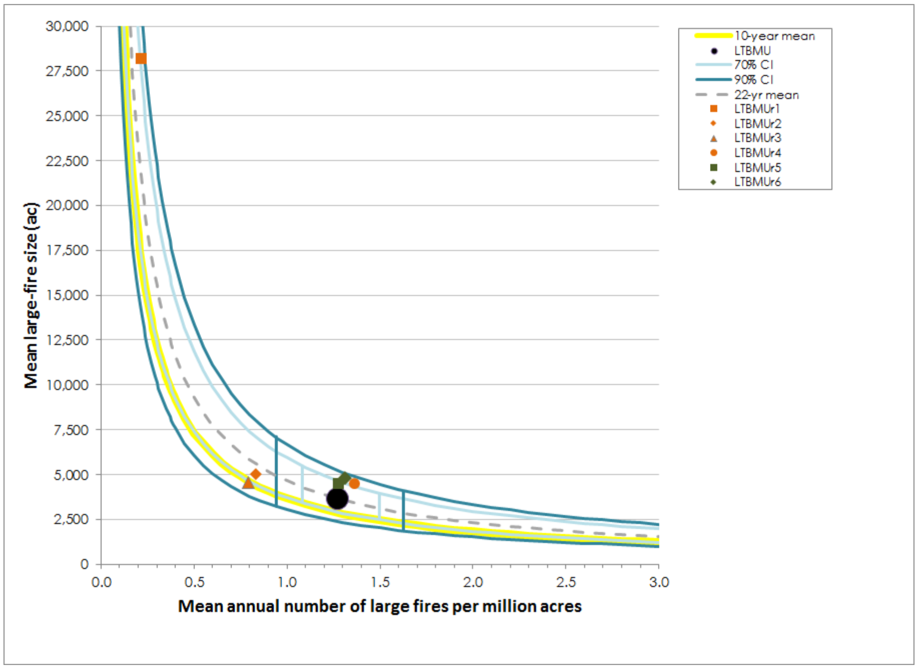
Well, look at that! We've now nailed the number of large fires, and the mean large-fire size seems to have held constant. A quick check of the fire-size distribution confirms that the fire-size calibration held quite well. All that is left is a full 10,000-iteration simulation.

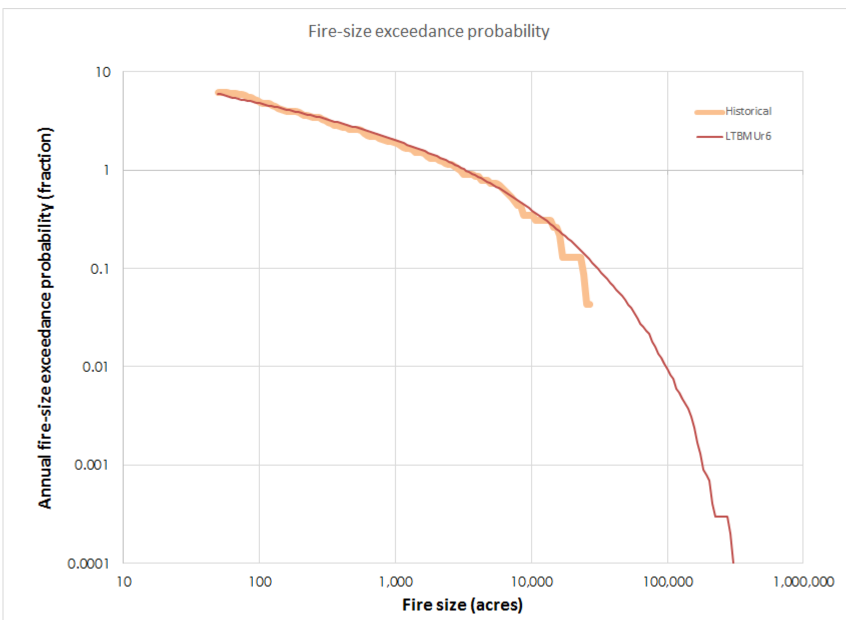




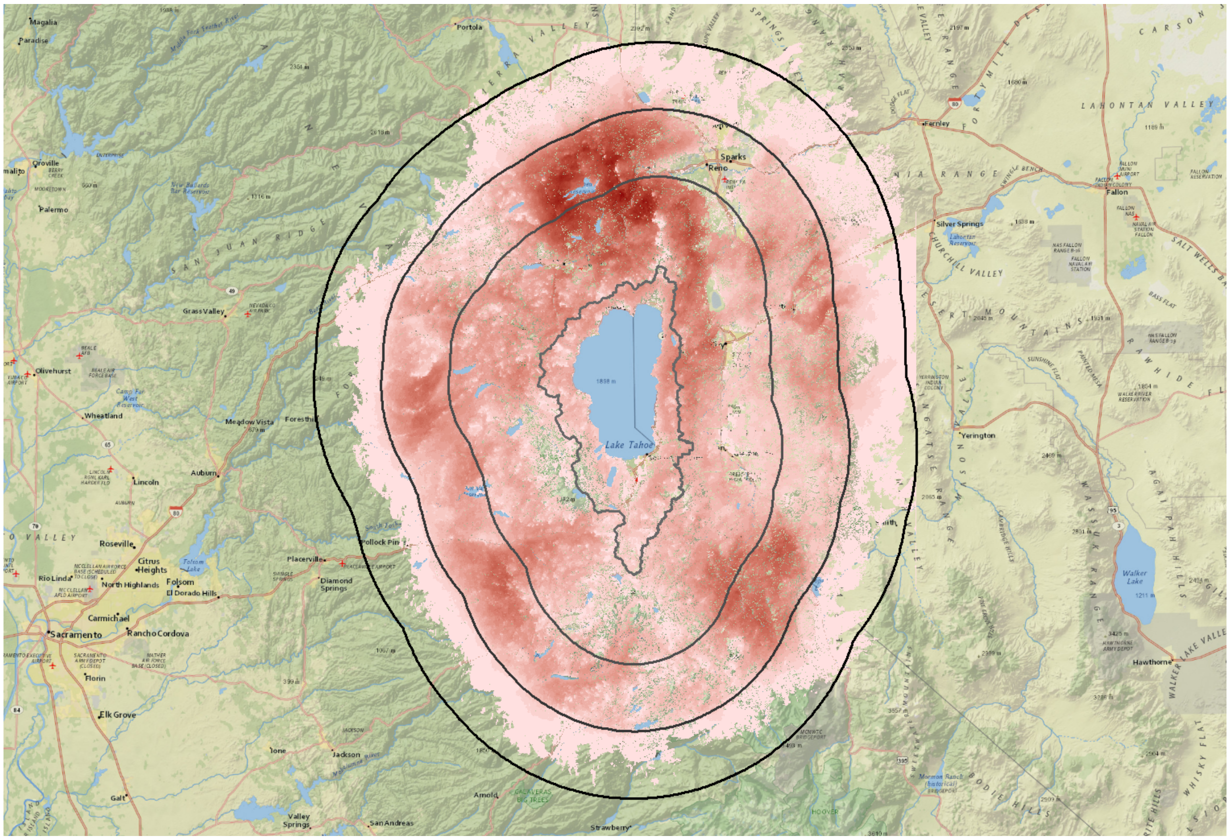
7.5.6 LTBMU Run 6

We expect Run 6 to be the final 10,000-iteration 120-m resolution simulation. It uses the same inputs as Run 5 but with 10,000 iterations. This final run simulated a total of 148,321 fires, of which just 24.2% (35,843) reached the large-fire threshold. Compared to the 3,000-iteration simulation, Run 6 fires were slightly larger, and therefore a few more of them reached the large-fire threshold. Even though the simulation is on the upper end of the bootstrapped confidence intervals, another look at the fire-size distribution gives reason to accept this run as final.





You may have noticed that the fire-size distribution charts shown on these pages include simulated and historical fires as small as 50 acres, and that FSim is doing a very reasonable job of simulating that portion of the fire-size distribution. (After examining these graphs with different fire-size cutoffs, we have noticed that FSim's fire-size distribution results are fairly reasonable down to about 4-5 pixels; below that, artifacts start to show up.)



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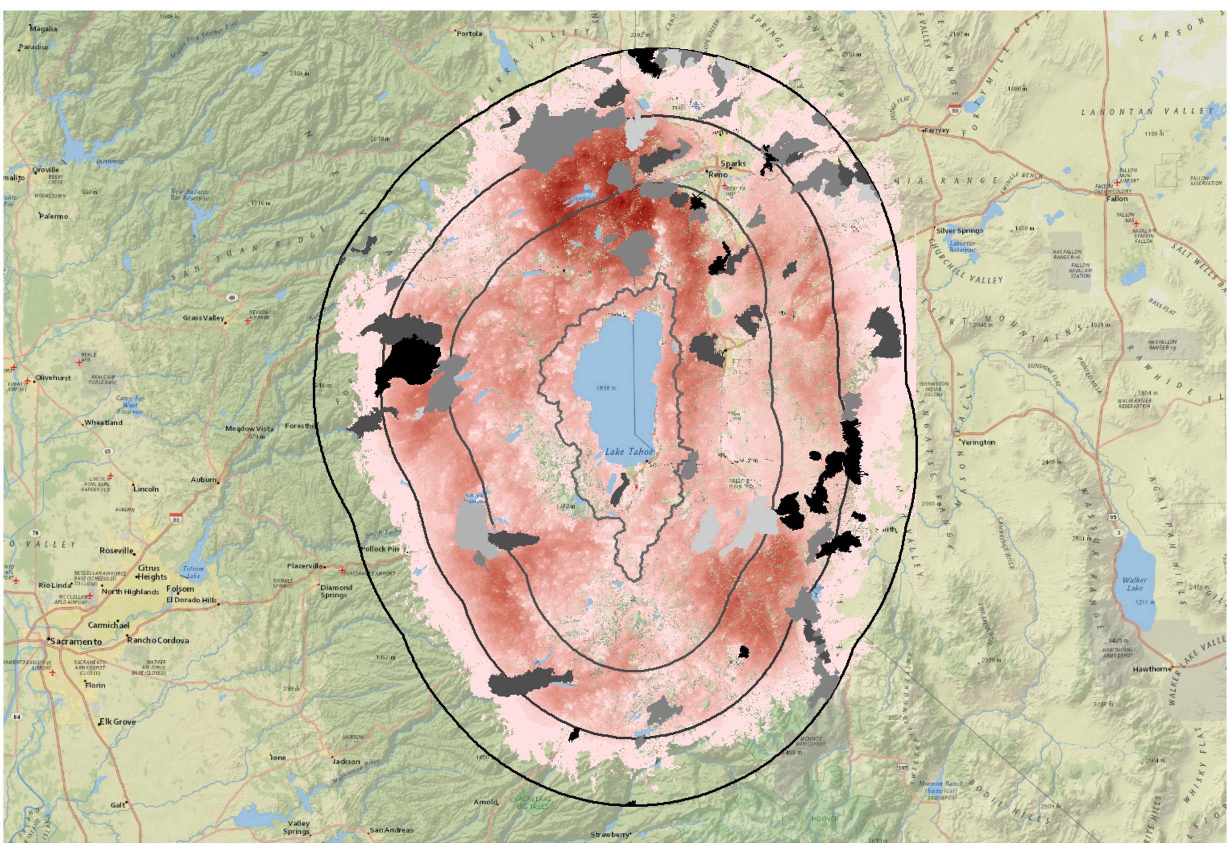
Grass Valley
Olivehurst
Wheatland
Meadow Vista
Lincoln
Auburn
Lake Tahoe
Yerington
Roseville
Citrus Heights
Rio Linda
North Highlands
Folsom
El Dorado Hills
Placerville
Pollock Pines
Diamond Springs
Carmichael
Sacramento
Rancho Cordova
Florin
Elk Grove
Walker Lake
Hawthorne
Ione
Jackson
Galt
Arnold
Valley Springs
San Andreas
Strawberry
LAHONTAN VALLEY



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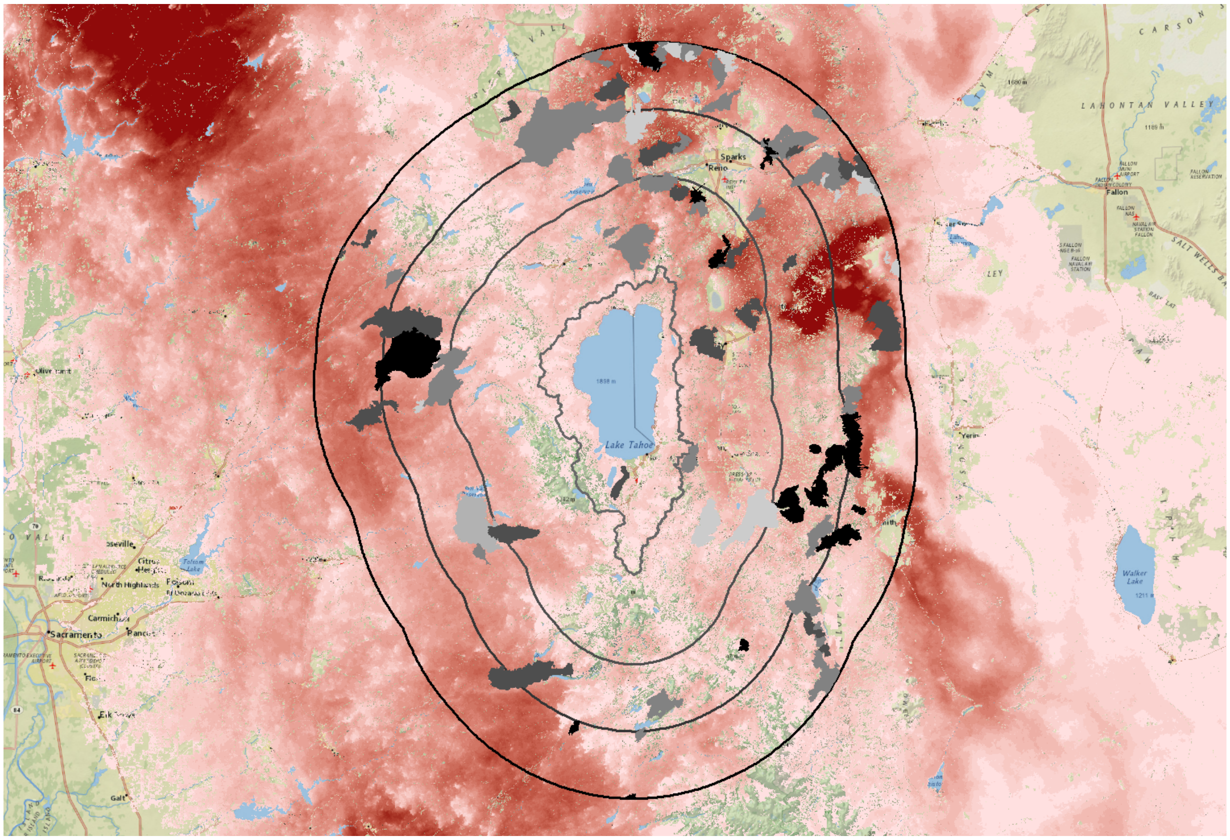

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North Highlands
Galt
Fallon
Walker Lake
LAHONTAN VALLEY

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FSim utilities

8 FSim utilities

A few utilities for working with FSim are included with this guide. They fall into two classes: Excel workbooks and a Python script. None of these is utilities needed to run FSim, but they make working with FSim much easier. All utilities are provided as-is with no warranty. The user of these utilities is solely responsible for their accuracy.

8.1 Historical occurrence workbook

An Excel workbook template for summarizing historical large-fire occurrence is provided with this guide. The current version is [FOA]_HxOcc_v2017.01.xlsx. Save a copy of this file and replace the [FOA] with the name of the fire occurrence area it represents. The template is primarily for summarizing large-fire occurrence, not all fires, so it is limited to 30,000 fire records. This limit should be sufficient even when using a relatively small large-fire threshold, such as 10 acres.

The Historical occurrence workbook is provided as-is with no warranty. The version provided contained no known errors at the time it was generated, but could easily contain unknown errors. Please report any errors to us by email. The workbook is not user-friendly software that will protect you from yourself; there is little or no protection from inadvertently overwriting important formulas. Nonetheless, the calculations and summaries contained in the workbook are important for making the best use of FSim.

Proceed with caution.

Workbook Setup

Step 1

Generate a tabular FOD for the fire occurrence area; you must know the acreage of the FOA. The Short (2013) FOD is an excellent source of historical fire-occurrence data. The only attributes used in this workbook are the start date and final fire size. Isolate these two fields and sort them from oldest to newest. Verify that the fire-occurrence data includes no more than 30,000 records. Copy those records to the clipboard.

Step 2

Switch to the **DataTable** worksheet and paste as values (Shift-Ctrl-V) the START DATE and FINAL SIZE fields of your FOD into the orange-highlighted cells (columns B and C).

Step 3

Switch to the **FireSeasonSummary** worksheet, and use the filter button on the cell B5 (JulianDate) to sort this list from smallest to largest.

Step 4

Switch to the **TabularSummary** worksheet and fill in all of the orange-highlighted cells with information about the FOA:

FOA name--provide a short name or number that identifies the fire occurrence area.
FOD source--provide a brief description of the source of fire-occurrence data.

FOA area (landscape)--Enter the land area of the FOA on which this historical information will be applied in FSim (in acres). This area could be larger or smaller than the land area for the historical information itself (see below).
FOA area (historical)--Enter the land area covered by the FOD (in acres).
Large-fire season definition--In cell C49, enter the threshold percentage of large-fire occurrence to be used to identify the start and end of the large-fire season.
Include year--In the orange-highlighted cells in G5:G30, enter a value of 1 for the years included in the FOD on the DataTable worksheet, otherwise enter a 0. This is mostly for carrying forward to future years as the FOD includes recent fire seasons.

All calculations, graphs and tables should update automatically. There will be some stochastic variation in the bootstrap means and confidence intervals for number of large fires and large-fire area burned. Those values will change every time the workbook is refreshed.

Print the TabularSummary worksheet to a PDF or hardcopy, but also save the Excel workbook. You'll need to copy some data from this worksheet into another FSim Calibration[108] workbook. The print area is pre-set for the layout of this worksheet. It should print four pages.

Interpretation

Page 1 of the layout tabulates high-level summaries of large-fire occurrence, including FSim calibration targets for the number and mean size of large fires, and mean annual area burned. The graph below the table is a fire occurrence characteristics chart, which plots the mean annual number of large fires against the mean large-fire size. The curving reference lines represent equal mean burn probabilities. Each FOA will plot as a point somewhere on this graph.

Page 2 has information about the seasonality of large fires (and smaller fires if those could be included in the FOD pasted into the DataTable worksheet). The table at the top of this page summarizes some measures of the start and end of the large-fire season, defined as the dates within which a specified percentage of large-fires occurs (measured either by number of large fires or by large-fire area burned). The percentage is specified in the orange-highlighted cell C49 on the TabularSummary worksheet. For these dates to be valid, Step 3 show above must be completed first.

Below the table is a "Pyramid" chart that plots final fire size against the Julian day of fire discovery for all fires in the FOD pasted into the DataTable worksheet. The large-fire size threshold is shown as a heavy dashed line. The vertical green lines show the large-fire season as measured by area burned--the specified percentage of large-fire area burned occurs with fires starting between those Julian dates.

Page 3 summarizes the annual large-fire occurrence--annual large-fire number and area burned--from 1992 to the most-recent year of your FOD. The orange-shaded cells in column G are used to identify which years are actually included in the FOD. This is typically used for the most recent fire years, which may or may not yet be included in the FOD. The graph on the right is a graphical display of the tabular data. The two small tables on this page are summaries of the central tendency of the number and size of large fires, and of the confidence intervals around the mean number and total area burned. The blue-shaded cells will eventually be copied to the FSim calibration worksheet for the same FOA.

Page 4 is a graph showing large-fire area burned over the historical period, including the mean (with confidence intervals) and the running 10-year mean.

8.2 FSim Calibration workbook

An Excel workbook template for summarizing a number of FSim runs for a fire occurrence area is provided with this guide. The current version is [FOA]_FSim Calibration_v2017.01.xlsx. Save a copy of this file and replace the [FOA] with the name of the fire occurrence area. The limit on the number of simulated fires in each run is 999,990. If you have a run with more records than that, try removing fires below your nominal large-fire size (e.g. 100 ha). Some functionality, such as the large-fire fraction and suggested AcreFract will no longer be valid, but everything else will be.

The FSim Calibration workbook is provided as-is with no warranty. The version provided contained no known errors at the time it was generated, but could easily contain unknown errors. Please report any errors to us by email. The workbook is not user-friendly software that will protect you from yourself; there is little or no protection from inadvertently overwriting important formulas. Nonetheless, the calculations and summaries contained in the workbook are important for making the best use of FSim.

Proceed with caution.

Workbook Setup

Step 1--Fire modeling landscape (fuelscape) worksheet

The worksheet allows you to paste data about your fuel model grid and summarizes the data to produce graphs of the distribution of fuel models on the fire modeling landscape. Begin by generating a table that lists the FBFM number in one column and the number of pixels in the next column. You can do this in a number of ways, including with the Zonal Statistics tool in ArcMap. Paste those data into the blue-shaded cells in Columns R and S. The graphs on this page will automatically update. Enter the pixel size in cell V1; this will correctly convert pixels into acres.

Step 2--HxOcc worksheet

The blue-shaded cells in the HxOcc worksheet contain information about historical large-fire occurrence in the FOA. These data can be copied directly from the blue-shaded cells on the Historical Occurrence 106 workbook and pasted (as values) here--the layout is identical. Otherwise, type in the historical occurrence values for the FOA.

Step 3--FireSizeLists worksheet

First, obtain a historical fire-size list for the FOA. For this worksheet you will only need the sizes, not dates or causes. Sort that fire-size list from largest to smallest, then paste the values into column A. Simulated fire-size lists will be pasted in columns to the right of this.

Step 4--Calibration Table worksheet

Skip ahead a few worksheets to the Calibration Table worksheet. In cell C3 enter the FOA area for historical occurrence (in acres), and the the adjacent cell D3 enter the FOA area for simulation. In most cases these will be the same. In cell C4 enter the large-fire size threshold; this should be the same threshold used on the Historical Occurrence workbook. In cell C12 enter the number of years in the Fire Occurrence Database used to make the inputs in steps 2 and 3.

Using the Calibration Workbook after each simulation

After a simulation has been completed you can populate the workbook with inputs and outputs related to that simulation. Calculations and summaries will be automatically generated.

Step 1--ADJ worksheet

This optional worksheet allows you to track different versions of Rate of Spread adjustment factors used in successive simulations. It also allows you to easily generate a new ADJ. For the first simulation, enter into the blue-shaded cells the ADJ values used for your simulation. If your ADJ file does not list an ADJ value for a fuel model, enter 1.0 for that fuel model, because that is what FSim will do anyway.

When deciding on new ADJ values to use for the next simulation, you can copy-and-paste into a new column, and then use the drop-down box in cell X1 to select that new ADJ version. Doing so populates column X with values from the selected ADJ. To make a new .adj file, select cells W3:X42 and copy to the clipboard (Ctrl-C). In a text editor with a blank file, paste the text (Ctrl-V) and save with an appropriate filename.

Step 2--CMDX worksheet

You will paste the contents of your command file into the CMDX worksheet. This not only provides tabular documentation of successive runs, but the workbook also uses command-file values in calculations, such as NumSimulations.

Open your command file in a text editor, select all text (Ctrl-A) and copy to the clipboard (Ctrl-C). Switch to this worksheet and place the cursor in cell A2 (if this is the first simulation for the FOA) and paste (Ctrl-V). The contents may need to be parsed, or they may parse automatically. To parse, keep the pasted data highlighted and select Data > Text to Columns > Delimited > Space (delimiter) > Finish. You may need to accept the overwriting of any existing data in the adjacent column.

Step 3--FireSizeLists worksheet

Switch to the FireSizeLists worksheet and paste-as-values (Shift-Ctrl-V) the simulated firesizelist 57 into the appropriate column (which should now be labeled with the OutputsName). It is good practice to sort the fire-size list from largest to smallest before pasting.

The fire-size list is a standard FSim output in text file format. Open it in Excel and parse the text into columns (space-delimited). Verify that the number of records is less than 999,990. Find the correct column for the fire size field, sort from highest to lowest, copy this column of data and paste-as-values into the appropriate column.

Step 4--Calibration Table

In the appropriate column of row 13, enter the AcreFract value used in the simulation. This value is recorded in the .fdist file identified in row 20. The input and output information in this table will now be up to date for the simulation.

Step 5--Calibration Chart

Now switch to the Calibration Chart worksheet, which is a fire-occurrence characteristics chart. Even without a completed simulation, this chart shows the historical fire-occurrence characteristics--mean and confidence intervals around the number of large fires and large-fire area burned. Those two values imply a mean large-fire size (Y-axis).

The result for a simulation will plot as a point on this chart. By comparing where that point falls on this chart you can see whether you need fires to be generally larger or smaller, and whether you need more or fewer of them.

Revision history

9 Revision history

Version	Date generated	Notes
0.1.1	October 2016	Working draft; updated constantly.
0.1.2	December 2016	Working draft; updated constantly.
0.1.3	January 2017	Working draft; updated constantly.
0.1.4	January 2017	Working draft; updated constantly.
0.2.0	February 2017	Added Calibrating FSim section (draft for FSim UG meeting)
0.3.0	February 2018	Edits made following review comments; added Appendices
0.3.1	March 2018	Additional edits made

- I -

- K -

- L -

- M -

- N -

- O -

- P -

- R -

- S -

- T -

- V -

- W -