New and Revised Fire Effects Tools for Fire Management

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Introduction

Announcing the release of new software packages for application in wildland fire science and management, two fields that are already fully saturated with computer technology, may seem a bit too much to many managers. However, there have been some recent releases of new computer programs and revisions of existing software and information tools that deserve mention because they constitute a suite of technology that can be used to effectively integrate fire ecology into fire management.

Computer tools that synthesize fire effects research into a software application or data structure are important to all phases of fire management. In planning, fire effects tools can be used to design fuel treatments, develop burn prescriptions, allocate available fire management resources, predict future fire effects, and prioritize areas for treatment. In real-time operational settings, these tools can be used to quantify adverse fire effects, evaluate the benefits of wildfire, determine smoke emissions, and determine values at risk. After a fire has passed, the tools can be used to predict secondary effects, evaluate regeneration potential, and prioritize rehabilitation efforts. Indeed, most fire management applications should include evaluations of fire effects to fulfill all management objectives.

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Information Technology

Fire Effects Information System: FEIS-Spatial

The Fire Effects Information System (FEIS), now in its 27th year, continues to provide managers with online syntheses of scientific knowledge about plants and animals and their relationships with fire. FEIS now contains reviews of more than 1,100 species, including extensive recent reviews of invasive plants. FEIS reviews offer a wealth of information for resource management, restoration, rehabilitation, and fire management. The system is heavily used—nearly half a million visitors from throughout the United States and more than 90 other countries visited the FEIS Web site in 2012.

In summer 2012, FEIS introduced a new, spatially searchable user interface, which is currently being tested at <http://www.feis-crs.org/beta> (figure 1). FEIS-Spatial offers users many new features, including the ability to search for species reviews and fire studies by (1) State, province, or country; (2) plant community; (3) national park, forest, refuge, reservation, or other Federal land; (4) plant, animal, lichen, or fungus; and (5) invasiveness and nativity.

The newest product available in FEIS is a collection of fire regime syntheses, which describe historical fire regimes and current changes in fuels and fire regimes for groups of plant communities described by LANDFIRE (figure 2). The first two of these syntheses, covering the Alaskan tundra and all of Hawaii, were published in early 2013. More will be published as they are completed and reviewed. Go to <http://www.fs.fed.us/database/feis/fire_regime_table/BpS_fire_regime_table.html> for a list of fire regime syntheses completed and underway.

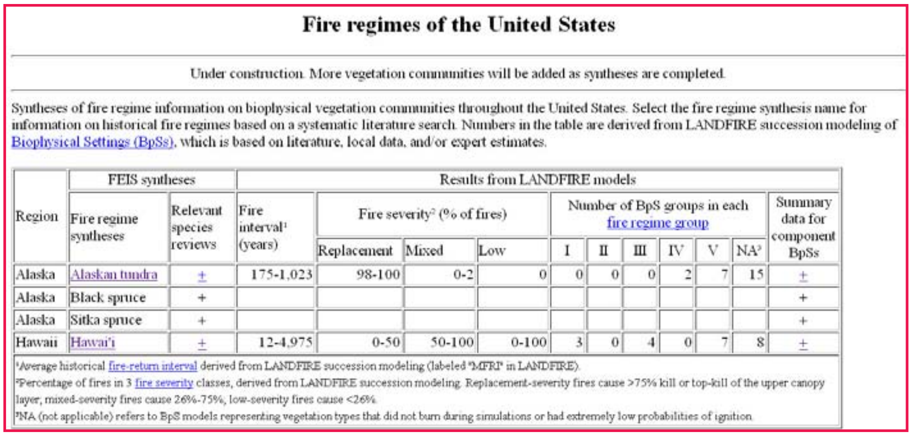
Computer tools that synthesize fire effects research into a software application or data structure are important to all phases of fire management.

Severe Fire Potential Map (SFPM)

Digital maps of burn severity are widely used to describe the spatial distribution and magnitude of fire effects on vegetation and soils in recently burned areas. Examples include the Burned Area Reflectance Classification data produced to support Burned Area Emergency Rehabilitation efforts (Clark and McKinley 2011), the Rapid Assessment of Vegetation Conditions products to assess overstory vegetation loss immediately post-fire (Guay 2011), and the Monitoring Trends in Burn Severity (MTBS) (<http://www.mtbs.gov>) products that have provided a fire atlas of large fires and their severity since 1984. Among other uses, these types of post-fire severity assessments help to identify when and where to mitigate adverse fire effects, plan post-fire fuel management activities, and describe landscape-scale ecological conditions. What these products don't provide, however, are predictions of those areas most likely to experience severe fire effects in future fire events. To fill this void, the Severe Fire Potential Map (SFPM) was produced.

The SFPM is a comprehensive 30-meter-resolution raster dataset covering the conterminous Western United States (figure 3). It depicts the potential for fires to result in high-severity effects if they should occur on a 0 to 100 scale. This dataset is intended to be an online resource that managers can download and use to evaluate the potential ecological effects associated with new and potential fire events. It can also be used to aid strategic fire management planning, including prioritization and placement of fuels treatments across large landscapes.

Figure 1.—*The new front page of the Fire Effects Information System (FEIS).*



Fire regimes of the United States

Under construction. More vegetation communities will be added as syntheses are completed.

Syntheses of fire regime information on biophysical vegetation communities throughout the United States. Select the fire regime synthesis name for information on historical fire regimes based on a systematic literature search. Numbers in the table are derived from LANDFIRE succession modeling of Biophysical Settings (BpSs), which is based on literature, local data, and/or expert estimates.

Region	FEIS syntheses		Results from LANDFIRE models										
	Fire regime syntheses	Relevant species reviews	Fire interval[1] (years)	Fire severity[2] (% of fires)			Number of BpS groups in each fire regime group						Summary data for component BpSs
				Replacement	Mixed	Low	I	II	III	IV	V	NA[3]	
Alaska	Alaskan tundra	+	175-1,023	98-100	0-2	0	0	0	0	2	7	15	+
Alaska	Black spruce	+											+
Alaska	Sitka spruce	+											+
Hawaii	Hawai'i	+	12-4,975	0-50	50-100	0-100	3	0	4	0	7	8	+

[1]Average historical fire-return interval derived from LANDFIRE succession modeling (labeled "MFRI" in LANDFIRE).
[2]Percentage of fires in 3 fire severity classes, derived from LANDFIRE succession modeling. Replacement-severity fires cause >75% kill or top-kill of the upper canopy layer; mixed-severity fires cause 26%-75%; low-severity fires cause <26%.
[3]NA (not applicable) refers to BpS models representing vegetation types that did not burn during simulations or had extremely low probabilities of ignition.

Figure 2.—*An example of output from the Fire Regime Synthesis product in Fire Effects Information System.*

The SFPM builds on satellite-derived observations of burn severity from MTBS for more than 7,000 fires that burned between 1984 and 2007. Random Forest statistical models were built relating severe fire occurrence to a set of environmental conditions for forested and nonforested settings in each of 17 mapping regions by sampling locations that have experienced high-severity fire, as well as those that did not. Environmental variables considered in the Random Forest models included a suite of topographic descriptors including elevation and maximum potential solar radiation, 1,000-hour fuel moisture percentile at the time of each fire, and density of pre-fire green vegetation as expressed by the Normalized Difference Vegetation Index (NDVI). Classification accuracies for individual models ranged from 65 percent to 83 percent for forest models, and 69 percent to 82 percent for nonforest models. Elevation, 1,000-hour fuel moisture, and NDVI were always among the five best predictor variables, often with some combination of slope, broad-scale topographic position, and solar radiation.

To map severe fire potential across the landscape, the statistical models were used to predict how likely severe fire effects would be for each 30-meter pixel, conditional on that pixel's experiencing fire at a particular percentile level of 1,000-hour fuel moisture. It is important to note that the 1,000-hour fuel moisture percentiles were inverted so that higher percentiles reflect drier conditions, consistent with the way fire managers are accustomed to referring to other fire weather indices such as the Energy Release Component.

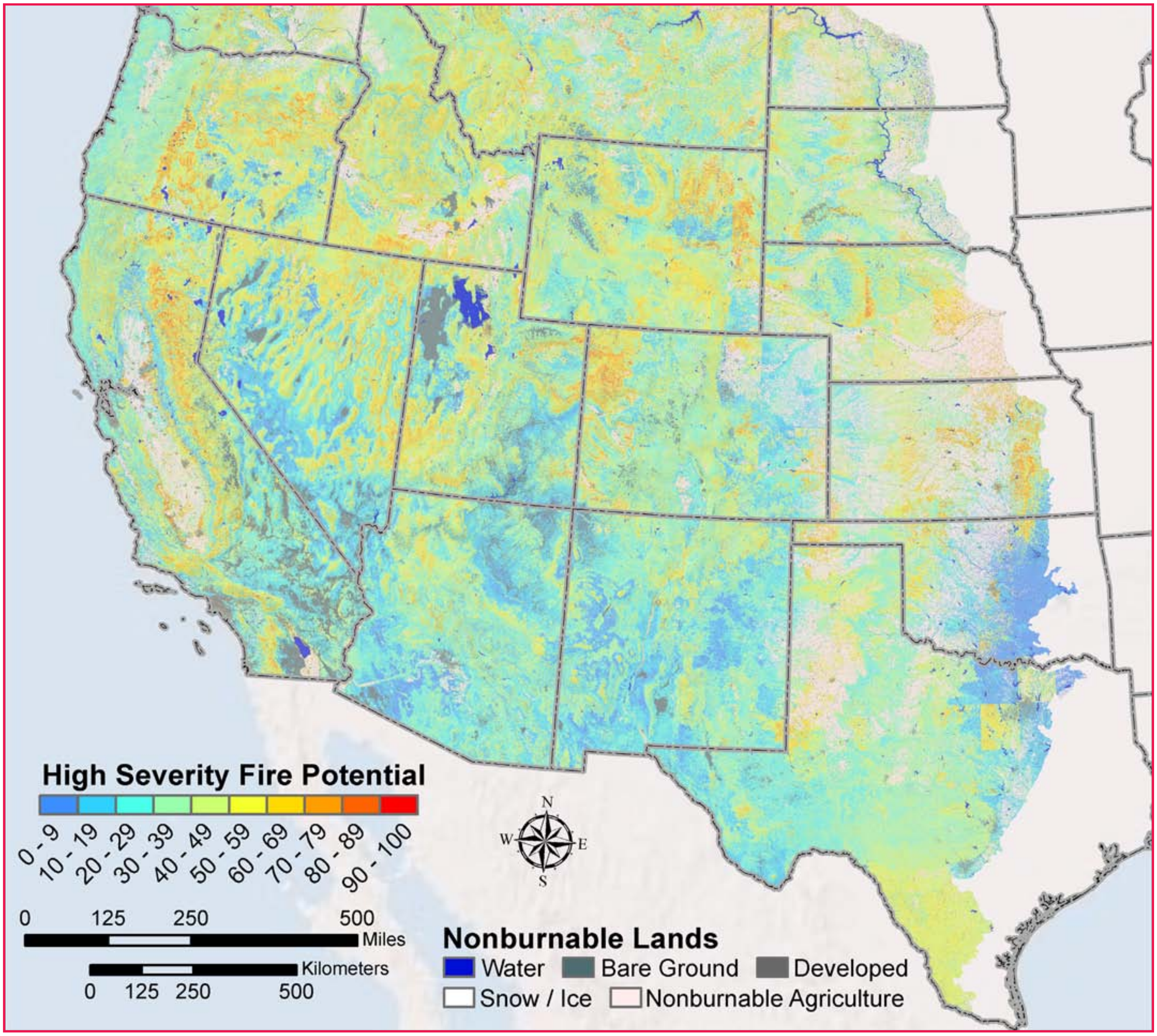


Figure 3.—*The Severe Fire Potential Map product.*

For our spatial predictions, the 1,000-hour fuel moistures were set as constant across the entire landscape. The SFPM was initially built using the 90th percentile (i.e., very dry) fuel moisture conditions, but it could easily be generated for other fuel moisture conditions as well. Our SFPM also used NDVI calculated from 2011 Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery to reflect current vegetation condition. Again, updated versions of the SFPM could be easily generated in the future by using newer MODIS NDVI mosaics. Mosaics of the 90th percentile SFPM by our 17 mapping regions and by forest and woodland versus nonforest settings are available online at the FRAMES Web site (<http://www.frames.gov/firesev>).

Inventory and Monitoring

FEAT-FIREMON Integration

Inventory and monitoring tools are needed for many diverse purposes such as quantifying fuels inputs to fire behavior and effects simulation models, monitoring changes in fuels and ecological characteristics after treatment or wildfire, and calculating fuels tools in fire management. Most current classification applications have inherent constraints that limit their scope. Standardized protocols and methods for measuring ecological characteristics, especially fuels attributes, are essential for successful fire management.

Digital maps of burn severity are widely used to describe the spatial distribution and magnitude of fire effects on vegetation and soils in recently burned areas.

In 2005, Lutes et al. (2006) released the first version of the FIRE MONitoring and inventory system (FIREMON), an integrated database and computation system that contained standardized methods for collecting a suite of ecological characteristics, including fuel data, which were linked to a set of ACCESS databases for the entry of those data. It also contained a set of computation queries linked to the databases that calculated numerous other ecological characteristics, such as fuel loading.

Many people have adopted FIREMON protocols for their agencies and organizations. However, the National Park Service had already been using a set of protocols and tools called FEAT (Fire Effects Assessment Technology) for the same applications, so it became evident that any new revision of FEAT or FIREMON should integrate the two tools into one, and this integration was creatively called FEAT-FIREMON Integration (FFI) (Lutes et al. 2009). Recently, FFI was upgraded to create version 3.1 (figure 4).

FFI is an interagency, science-based, ecological monitoring software application that is designed to help managers meet mandated monitoring requirements. It is used by the Forest Service; the U.S. Department of the Interior's National Park Service, Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Geological Survey, and Bureau of Indian Affairs; tribes; State and local governments; nongovernmental organizations; and universities. FFI is a robust vegetation and fuels monitoring tool used to consistently describe ecological systems and monitor change over time. It incorporates the components necessary to conduct a successful monitoring program, including an integral database, analysis and reporting tools, and modular Geographic Information Systems component.

In July 2012, the FFI development team released FFI v1.04.02, which added customizable tree data reports and a save-data queries ability, bug fixes, and other user-requested updates. Additionally, work is underway on "FFI-lite," which is a more compact installation of FFI to be used on field computers and by users who do not need the full functionality of a Structured Query Language (SQL) server. FFI information and software are available at <http://www.frames.gov/ffi>.

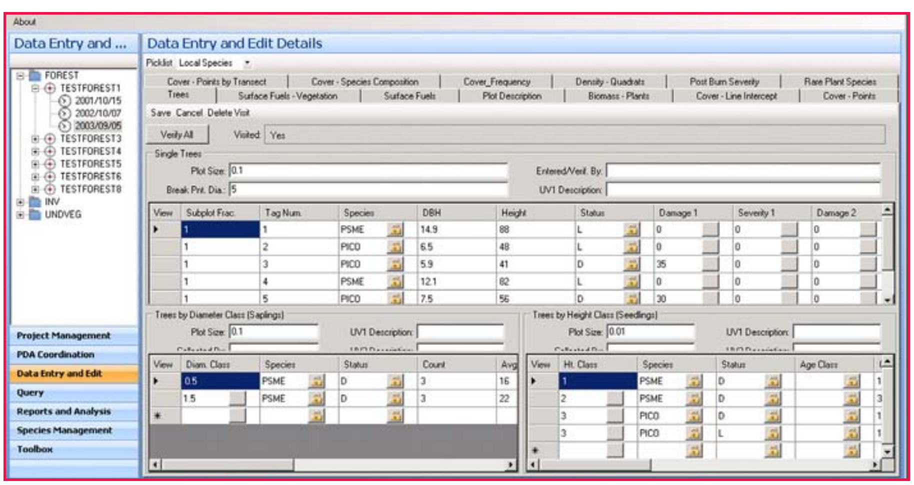


Figure 4.—*The newest version of the FEAT FIREMON Integration package.*

Fuel Treatments and Ecological Restoration

First Order Fire Effects Model

Version 6.0 of the First Order Fire Effects Model (FOFEM) has just been released and is now available to compute the direct or immediate consequences of fire (figure 5). Currently, FOFEM provides quantitative fire effects information for tree mortality, fuel consumption, mineral soil exposure, smoke, and soil heating.

FOFEM is national in scope and uses four geographical regions: Pacific West, Interior West, Northeast, and Southeast. Forest cover types provide an additional level of resolution within each region. Geographic regions and cover types are used both as part of the algorithm selection key and as a key to default input values.

FOFEM is a computer program that was developed to meet the needs of resource managers, planners, and analysts in predicting and planning for fire effects (Reinhardt and Keane 1998). Quantitative predictions of fire effects are needed for planning prescribed fires that best accomplish resource needs, for impact assessment, and for long-range planning and policy development.

Most fire effects research has tended to be empirical, and thus limited in applicability to situations similar to those under which the research was conducted. Additionally, fire effects research results have not previously been assembled in a common format that is easily accessed and used, but rather have been scattered in a variety of journals and publications.

In developing FOFEM, a comprehensive search of the fire effects literature was conducted to obtain all useful predictive algorithms. These algorithms have been screened to evaluate their predictions over a range of conditions. Thus, a major internal component of FOFEM is a decision key that selects the best available algorithm for the conditions specified by a user. The algorithms are incorporated into FOFEM in an easy-to-use computer program. Realistic default values, documented in detail in the "Help" section of the program, have been provided for many inputs, minimizing the data required. These defaults were derived from a variety of research studies. Any of these default values can be overridden by the user, allowing the use of this program at different levels of resolution and knowledge.

FOFEMv6 replaces its two predecessors—FOFEMv4, an IBM-PC DOS version developed in the early 1990s (Reinhardt et al. 1997), and FOFEMv5, an IBM-PC Windows version developed circa 2000. FOFEMv6 is functionally equal to FOFEMv5 but has a much improved user interface, graphical output, and a few other internal changes, including the following:

- Tree species codes are changed to standardized vegetation cover type codes,
- New Fuel Characteristics Classification System (FCCS) cover types and related foliage and branch fuels have been added,
- FFI tree data can now be imported directly into FOFEMv6 to compute mortality,
- The soil heating model has been refined, and
- A new tree mortality model for longleaf pine has been included.

FOFEM will be useful in a variety of situations including: (1) setting acceptable upper and lower fuel moistures for conducting prescribed burns, (2) determining the number of acres that may be burned on a given day without exceeding particulate emission limits, (3) assessing effects of wildfire and developing timber salvage guidelines following wildfire, and (4) comparing expected outcomes of alternative prescribed and wildfire management actions.

Consume

Consume is a decisionmaking tool designed to assist in prescribed burn and wildfire planning and assessment by using realistic fuels data. Consume predicts fuel consumption by combustion phase, pollutant emissions, and heat release based on input fuel characteristics, lighting patterns, fuel moistures, and other environmental variables.

Because Consume captures the inherent complexity of wildland fuels through a close interface with the FCCS (<http://www.fs.fed.us/pnw/fera/fccs>), specific fuel strata and categories can be targeted for prescription or noted as a potential source of pollutant emissions depending on the burn scenario. For example, a fuelbed with a developed organic soil layer (termed duff in Consume) may create a significant emissions source if burned under low duff moisture conditions. By evaluating a range of potential

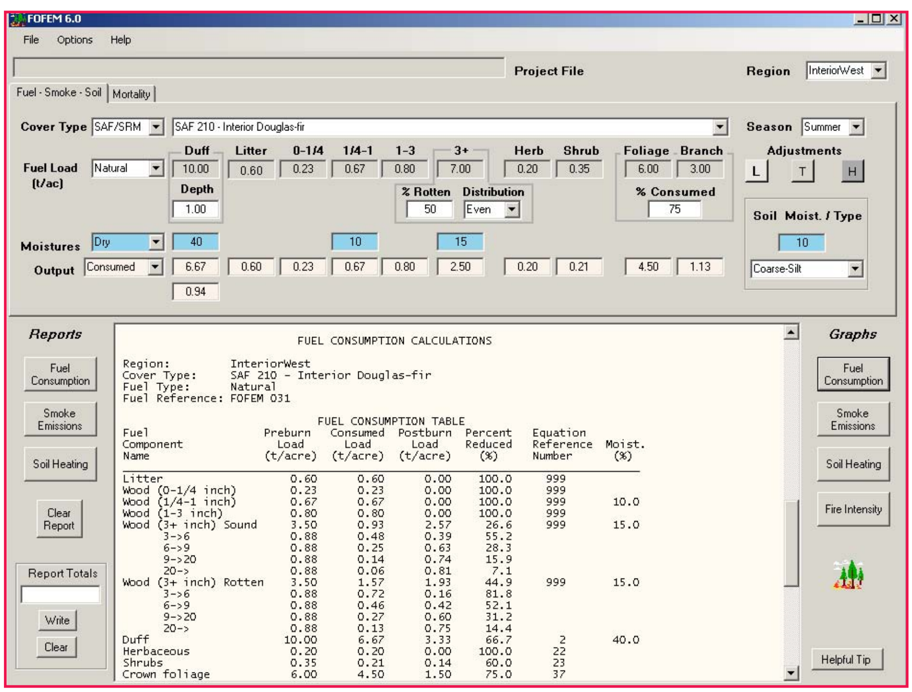


Figure 5.—*The new version 6.0 of the First Order Fire Effects Model.*

The Interagency Fuels Treatment Decision Support System provides a single, consistent user interface to access more than 50 fire effects and fire behavior tools.

burn scenarios, Consume users can target a suitable prescription window. With Consume, users can determine when and where to conduct a prescribed burn or plan for a wildland fire to achieve desired objectives, while reducing the impact on other resources.

Consume 1.0 included a set of consumption algorithms formulated from data collected at operational broadcast burns in logging slash. During the 1990s, the Fire and Environmental Research Application (FERA) team began developing models of fuel consumption by combustion stage for other fuel types beyond the Pacific Northwest and considering different configurations of fuels.

In addition, FERA began developing the new FCCS system, which allowed managers to select different fuel loadings for input into Consume. Consume 2.1 included calculations for activity-piled, activity-nonpiled, and natural fuels. Emission factors were also added to Consume 2.1, allowing estimation of emissions. Consume 3.0 included new consumption algorithms based on recent research on the flaming, smoldering, and residual combustion phases of western pine, southern pine, and boreal forests. The FCCS fuelbed input design was incorporated into Consume 3.0 to make use of the national fuelbed database of fuelbed loadings. Fuel loading values can be either imported from the FCCS or directly input by Consume users.

In 2002, FERA received funding from the Joint Fire Science Program (JFSP) to enhance Consume by predicting fuel consumption and smoke emissions in all wildland fuelbeds in the United States. Consume 3.0 included new consumption algorithms based on recent research on the flaming, smoldering, and residual combustion phases of western pine, southern pine, and boreal forests. The FCCS fuelbed input design was incorporated into Consume 3.0 to make use of the national fuelbed database of fuelbed loadings. FCCS contains a fuelbed reference library and calculates a wide range of fuel characteristics. Fuel loading values can be either imported from the FCCS or directly input by Consume users. In both software applications, fuelbeds are organized into six strata from canopy fuels to ground fuels.

The latest version of Consume (v. 4.1) was written in Python© and is being incorporated into the Wildland Fire Emissions Inventory System <http://wfeis.mtri.org> and the Interagency Fuels Treatment Decision Support System (IFTDSS) (figure 6) (see the Online Fire Effects and Fire Behavior Framework section later in this article). It will also be available as a stand-alone application. Consume 4.1 contains updated natural fuel consumption algorithms and emissions factors based on the latest available fuel consumption and emissions datasets.

FuelCalc

What has always been missing in the planning and design of fuel and ecological restoration treatments has been an easy and seamless link from plot data entered in data inventory databases to software that computes ground, surface, and canopy fuel characteristics from the plot data, and then to a simulation model that simulates the effect of a treatment on the entire fuel complex and subsequent fire behavior.

Figure 6.—*The newest version 3.1 of the Consume model.*

The Forest Vegetation System (FVS) currently performs these functions using the Fire and Fuel Extension (FFE), but it takes quite a bit of training to use FVS-FFE. Further, there are few graphic outputs for interpreting results, and it is not easy to contrast and compare treatment modifications. Moreover, most fire managers are not trained to run FVS-FFE; it is a tool for silviculturalists.

Enter FuelCalc (Fuel Calculation tool) (figure 6). This new software package allows for the direct import of surface and canopy fuel field data to calculate initial fuel conditions—such as surface fuel loadings (down dead woody, shrub, herb, duff, and litter), canopy bulk density, and canopy loading—and a variety of associated silvicultural characteristics such as timber volume and basal area. These data are interactively displayed to the user, who can then easily simulate the effects of harvest, thinning, pruning, piling, and broadcast burning on ground, surface, and canopy fuel characteristics.

FuelCalc was originally designed as a batch command line program to compute canopy fuel characteristics for mapping in the LANDFIRE prototype project (Keane et al. 2006). The JFSP program then decided to fund an expansion of FuelCalc to cover the computation of surface fuel loadings from FFI databases and the simulation of a wide variety of fuel treatments. The FOFEM, Burnup (Albini et al. 1995), and Nexus (Scott 1999) simulation models are embedded in FuelCalc to compute fuel consumption and crown fire behavior.

In general, FuelCalc is a software system for assisting local and regional fuel management planners

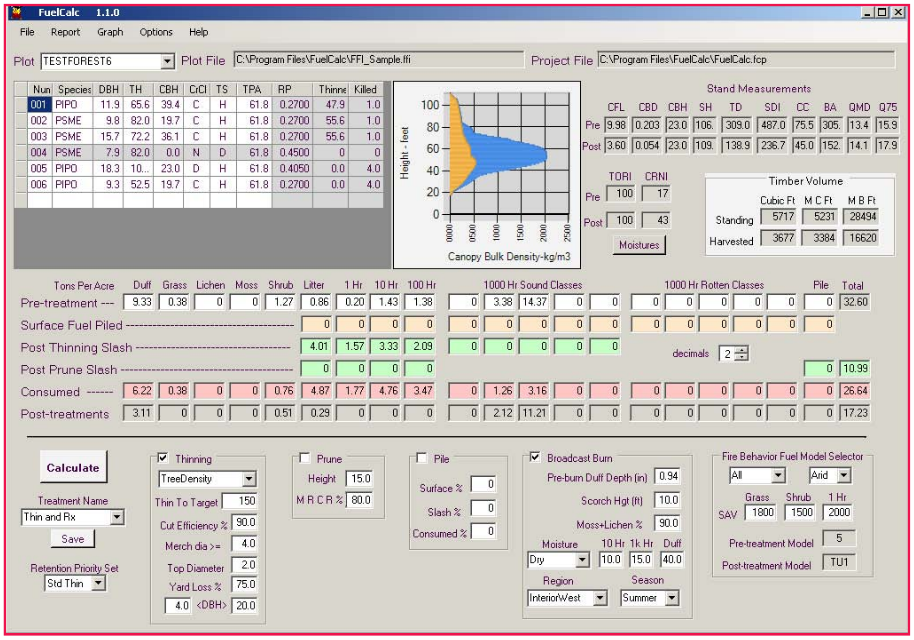


Figure 7.—*The first version 1.0 of the FuelCalc model.*

and related resource specialists in designing and implementing fuel treatments in forest stands (figure 7). The inherent spatial scale of FuelCalc is the plot or sample point (small group of integrated plots). FuelCalc has two primary applications.

First, FuelCalc is a tool to calculate current, or initial, canopy fuel characteristics at an inventory plot using a "treelist" (a listing of the characteristics of trees measured on a forest inventory plot) as input. The required tree characteristics for use in FuelCalc include tree species, diameter at breast height (dbh), tree height, crown base height, crown class (crown position), tree status, and the number of trees per acre represented by each tree in the treelist.

Second, FuelCalc is a tool for simulating the effects of a fuel treatment—thinning, pruning, pile burning, and broadcast burning—on ground, surface, and canopy fuel characteristics. In addition to the treelist inputs mentioned above, simulating the effects of a fuel treatment on canopy fuel characteristics requires a quantitative description of the treatment, including the type and intensity of thinning, the height of pruning, how much existing or activity fuel is to be piled, and the nature of a broadcast burn. Any combination of these four fuel management activities can be specified. In order to also simulate the effects of a fuel treatment on ground and surface fuel characteristics, FuelCalc requires a description of initial ground and surface fuel load, by size class.

In addition to the primary functions mentioned above, FuelCalc also has ancillary functions that may be useful to fuel management planners and silviculturists. From the initial surface fuel loads and from the loads after simulation of a fuel treatment, FuelCalc suggests a surface fire behavior fuel model that may be appropriate for the situation. If the fuel treatment simulation includes a broadcast burn, FuelCalc estimates fuel consumption and smoke production. FuelCalc also calculates several summary characteristics based on the initial or simulated treelist that may be useful to fuel treatment planners, silviculturists, or even wildlife biologists; these characteristics include stand height, stem density, Stand Density Index, canopy cover, basal area, quadratic mean diameter, and quadratic mean diameter 75th percentile.

FuelCalc's main purpose is to design, in detail, multiple fuel treatments to achieve a desired effect. FuelCalc is useful for planning fuel treatments, as well as for estimating the effects of wildfire on surface and canopy fuel characteristics. FuelCalc works by simulating changes in ground, surface, piled, and canopy fuel loads by size class as fuel treatments add to, or subtract from, the load in each class. FuelCalc input files can be created in the FFI ecological monitoring software (<http://www.frames.gov/ffi>) or by manually creating an input file in FuelCalc's standard format.

Wildland Fire Assessment Tool (WFAT)

The Wildland Fire Assessment Tool (WFAT) is a planning tool for generating fire behavior and fire effects maps for fire management (figure 8). It is a custom toolbar in ArcMap that provides an interface between the ArcGIS Desktop software and the FlamMap and FOFEM algorithms to produce these predictive maps. Fire behavior outputs include rate of spread, flame length, fireline intensity, fire type, and scorch height; fire effects outputs include soil heating metrics, emissions of common pollutants, fuel consumption of a variety of fuel classes, and tree mortality.

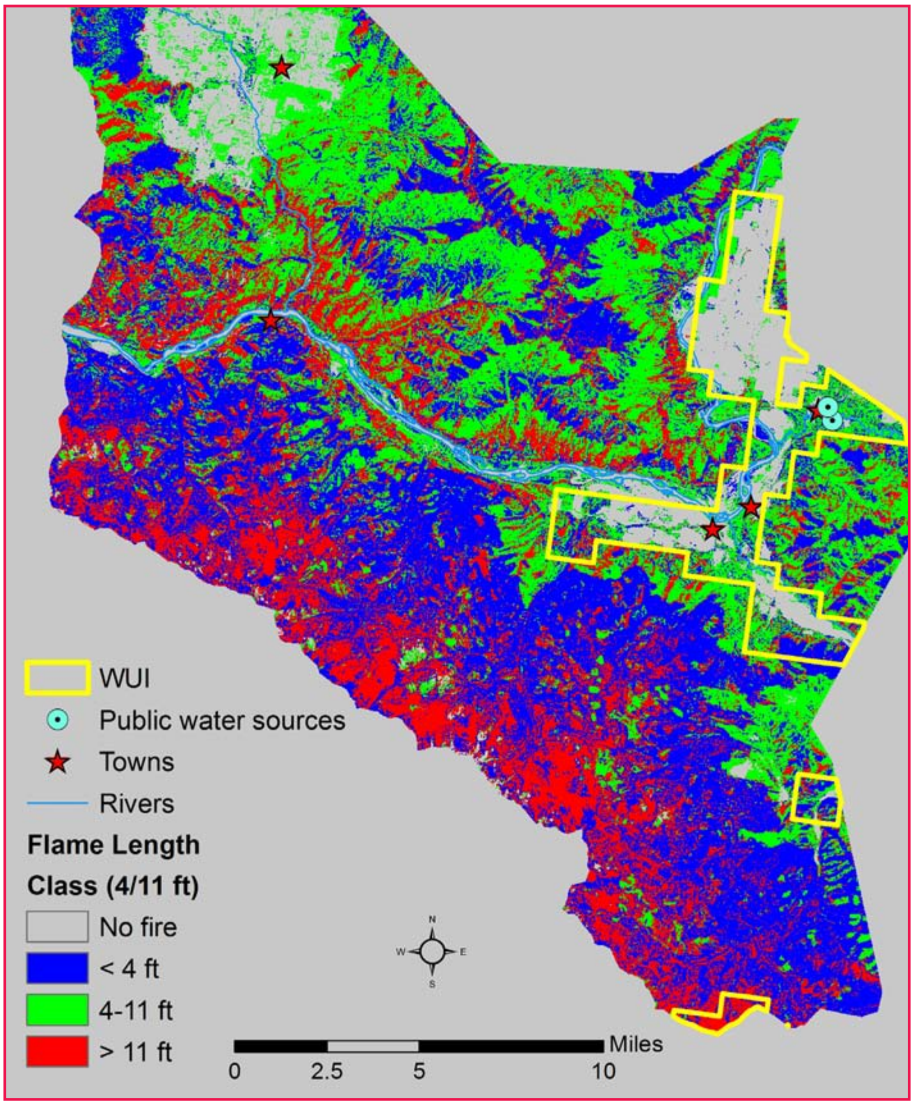


Figure 8.—*The Wildland Fire Assessment Tool Demo—ArcMap.*

The primary objectives behind the development of WFAT were to provide a tool that helps managers to prioritize fuel treatments on the basis of predicted fire behavior and effects and to assess the effectiveness of fuel treatment proposals in a geospatial context. WFAT provides decision support to land management planning by answering the question, *Where on a landscape are fire behavior and effects likely to be most problematic in regard to specific land management objectives?* Weather and fuel moisture conditions can be manipulated to simulate wildfire or prescribed burning conditions. The ArcGIS platform allows the user to integrate fire behavior and effects outputs with other spatial data, such as land ownership, areas of special concern, and digital imagery. WFAT uses spatial data in the ESRI Grid format and saves all outputs to the same format. LANDFIRE (<http://www.landfire.gov>) provides input data layers directly compatible with WFAT or local data can be used.

WFAT is the successor to the Fire Behavior Analysis Tool and the FOFEM Mapping Tool and incorporates the functionality of both tools into one convenient software application. WFAT also provides a landscape file (.lcp) generator and an import tool to convert FARSITE and FlamMap ASCII Grids

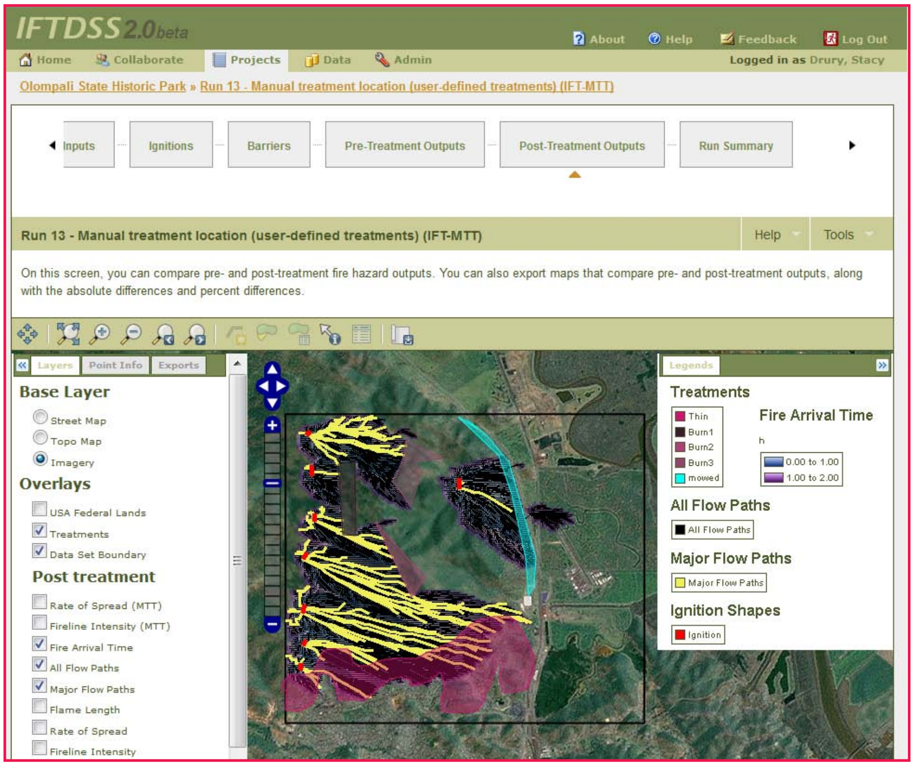


Figure 9.—*The Integrated Fuel Treatment Decision Support System integrated fire management tool.*

into ESRI Grid format for use in ArcGIS.

In summary, WFAT is a planning tool that can help fire and fuels managers to:

- Define and identify the location of hazardous fuel;
- Prioritize, design, and evaluate fuel treatment projects;
- Develop burn plans for prescribed fire;
- Predict fire behavior and effects for summary in planning and monitoring documents; and
- Calibrate fuel data layers based upon observed fire behavior.

WFAT was developed by the Fuels and Fire Ecology group within the Rocky Mountain Research Station Wildland Fire Management Research, Development and Applications (WFMRDA-FFE). The WFAT software, a user's guide, and tutorials are available for download at <http://www.frames.gov/wfmrda-ffe>. WFMRDA-FFE has also developed a short online course that introduces the theory behind WFAT and helps the user to quickly become proficient in using the tool for planning in fire and fuels management. For further information about WFAT, visit the Web site or email your questions to <helpdesk@niftt.gov>.

Online Fire Effects and Fire Behavior Framework: Interagency Fuels Treatment Decision Support System

The IFTDSS is a new Web-based software and data integration framework that organizes previously existing and newly developed fire and fuels software applications to make fuels treatment planning and analysis more efficient and effective. Fire and fuels managers can access the system at <http://iftdss.sonomatech.com.>

IFTDSS provides a single, consistent user interface to access more than 50 fire effects and fire behavior tools including simulation modules found in FOFEM, Consume, Behave, Randig, and FlamMap. The single portal for accessing data and models in IFTDSS reduces the amount of time a user needs to spend learning new interfaces and transforming data, thereby freeing up time for critical analysis of the work performed.

Fire effects, fire behavior, and risk assessment simulations are conducted within the IFTDSS using a set of stepwise workflows designed to address the business needs of land managers for planning fuels treatments and prescribed burns. The workflows within the IFTDSS provide access to data, simulation modules, and analysis tools in an intuitive, stepwise pattern (figure 9). Within the workflow concept, IFTDSS users have the ability to upload custom datasets, acquire and edit LANDFIRE data to reflect local conditions, conduct fire weather statistical analysis, simulate fire effects and fire behavior, assess potential fire hazards, evaluate risk to values within a landscape, and plan a prescribed burn using an online version of the interagency prescribed burn plan template.

The IFTDSS contains four workflows: hazard analysis, risk assessment, fuels treatment, and prescribed burn planning.

The hazard analysis workflow provides tools for performing a current-condition assessment of fire hazard within an area of interest. The focus of this workflow is to identify areas that warrant further analysis because of the potential fire hazard in those areas. High fire hazard is expressed by high potential fire behavior (e.g., flame length, rate of spread, and fireline intensity) or undesirable fire effects (e.g., tree mortality, smoke emissions, or excessive fuel consumption). Within IFTDSS, hazard analysis is viewed as the initial step in the fuels treatment and prescribed burn planning processes and is performed primarily at the landscape scale.

Risk assessment is a new and evolving process for fire management. Many fire managers have expressed a lack of direction on how risk should be assessed with respect to fuels treatment and managing harmful fire effects. In IFTDSS, risk is assessed based on expected loss or benefit due to burning. Risk is quantified using the response function concepts proposed by Calkin et al. (2010) to evaluate net value change across a landscape in the event of burning by wildfire under a set of environmental conditions. In the IFTDSS users can:

- Develop values-at-risk maps,
- Model fire behavior and burn probabilities across landscape,
- Model the expected loss of benefit for a value at risk resulting from fire, and
- Analyze potentials for applying fuels treatments to lower the potential for harm to values at risk owing to wildfire across landscapes.

Fuels treatments are designed to lower hazardous fire potentials and restore ecosystem resiliency temporally and spatially. In the IFTDSS fuels treatment planning workflow, users can evaluate potential fuels treatment options, including no-

Tool	Purpose	Type	Previous version	Changes	Web site
FEIS-Spatial	Provides syntheses of information on fire effects and fire regime characteristics	Searchable database of synthesis documents	FEIS	Syntheses searchable by multiple criteria, including geographic. New syntheses on fire regimes.	http://www.feis-crs.org/beta
SFPM	Depict the potential for severe fire to aid in evaluation of ecological effects of future fires	Landscape-level, raster geospatial data	New	There are no previous versions.	http://www.frames.gov/firesev
FFI	Application for collection, storage, analysis, reporting, and exporting ecological monitoring data	Plot-level, stand-alone program	FFI v1.04.02	Added custom tree report, added FuelCalc export, updated FVS export, updated data query tool.	http://www.frames.gov/ffi
FOFEM v6.0	Calculate fuel consumption, smoke emissions, soil heating, and tree mortality	Stand-level, stand-alone program	FOFEM v5.9	Complete redesign of GUI, new tree mortality equations, improvements in duff consumption, soil heating.	http://www.firelab.org/science-applications/fire-fuel/111-fofem
CONSUME 4.1	Predicts fuel consumption, emissions, and heat release	Stand-level, stand-alone program and batch processor	Consume 3.0	Updated natural fuel consumption and emissions factors; separated GUI from calculations to support batch processing.	http://www.fs.fed.us/pnw/fera/research/smoke/consume
FUELCALC v1.0	Design surface and canopy fuel treatments	Stand-level, stand-alone program	New	An old version of FUELCALC was a batch program that calculated canopy fuel characteristics.	http://www.firelab.org/science-applications/fire-ecology/228-fuelcalc
WFAT	Predicts fire behavior and fire effects spatially	Landscape-level extension to ArcGIS	FBAT and FOFEM Mapping Tool	Combines the functionality of FlamMap and FOFEM with display and analysis capabilities of ArcGIS.	http://www.niftt.gov
Online IFTDSS	Online system to predict fire behavior and fire effects spatially and aspatially for fuels treatment planning	Online, open source framework for plot-level and landscape-level analysis.	IFTDSS V1.2	New Web-based software and data integration framework that organizes existing and newly developed fire and fuels software applications.	http://ifdss.sonomatech.com

Table 1.—*A recently released suite of fire effects tools that are either new or revised to meet the needs of fire management.*

treatment, mechanical fuel removal and tree thinning, and prescribed burning. Additionally, users can identify where fuels treatments may have the greatest influence for mitigating wildland fire potential at the stand and landscape scales. In the IFTDSS, users can define and evaluate treatment strategies, locate treatments across landscapes, and assess the effectiveness of treatments for mitigating unwanted fire effects or fire behavior.

Prescribed burn planning and writing burn plans are critical duties for fire managers. All prescribed burns require a written plan that addresses how the burn will be conducted, the environmental conditions for burning, the expected fire effects and fire behavior, the resources needed to implement the burn plan, and plans for maintaining control of the burn.

In IFTDSS, users can simulate stand level fire effects and fire behavior potentials to develop burn prescriptions. Additional functionally is provided to conduct landscape level analysis for contingency planning and to provide maps for inclusion in the burn plan. The IFTDSS also contains an online template based on the *Interagency Prescribed Burn Planning Guide* (<http://www.nwcg.gov/pms/RxFire/rxfireguide.pdf>) and the Rx-341 prescribed burn plan writing course. This template allows users to input all data directly into the template and then generates a formatted burn plan that is compatible with Microsoft Word.

The current IFTDSS version 2.0 beta was released in October 2012. In early 2013, IFTDSS was evaluated by Carnegie Mellon's Software Engineering Institute (SEI). SEI is using a combination of nationwide instructor led workshops, virtual online workshops, inverviews, and questionnaires (Bennett et al. 2013). The SEI report concluded that IFTDSS represented an important paradigm shift in making software tools and support available to fire and fuels managers (Bennett et al. 2013). Additional information on IFTDSS can be found at <http://www.frames.gov/iftdss>.

Conclusion

This article does not present all fire ecology tools available for use in management; if interested, users should visit the FRAMES Web site (<http://www.frames.gov>). Table 1 lists fire effects tools that are either new or revised to meet the needs of fire management.

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References

Albini, F.A.; Brown, J.K.; Reinhardt, E.D.; Ottmar, R.D. 1995. Calibration of a large fuel burnout model. International Journal of Wildland Fire. 5: 173–192.

Bennett, C.M.; Brown, N.; Doney, D.; Parker-Gates, L.; Miller, S; Palmquist, M.S.; Place, P. 2013 Final report of the Ingeragency fuels treatment decision support system IFTDSS evaluation study. Special Report CMU/SEI-2013-SR-017. Pittsburgh, PA: Carnegie Mellon University. Software Engineering Institute. 142 p. <http://www.frames.gov/documents/iftdss/IFTDSS_SEI_FINAL_07-01-2013.pdf>. (21 March 2014).

Calkin, D.E.; Ager, A.A.; Gilbertson-Day, J., eds. 2010. Wildfire risk and hazard: Procedures for the first approximation. Gen. Tech. Rep. RMRS-GTR-235. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 62 p.

Clark, J.; McKinley, R. 2011. Remote sensing and geospatial support to Burned Area Emergency Response teams. Fire Management Today. 71(2): 15–18.

Guay, T. 2011. Rapid assessment of vegetation condition after wildfire. Fire Management Today. 71(2): 5–8.

Keane, R.E.; Frescino, T.L.; Reeves, M.C.; Long, J. 2006. Mapping wildland fuels across large regions for the LANDFIRE prototype project. In: The LANDFIRE prototype project: Nationally consistent and locally relevant geospatial data for wildland fire management. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 367–396.

Lutes, D C.; Benson, N.C.; Keifer, M.; Caratti, J.F.; Streetman, S.A. 2009. FFI: A software tool for ecological monitoring. International Journal of Wildland Fire. 18: 310–314.

Lutes, D.C.; Keane, R.E.; Caratti, J.F.; Key, C.H.; Benson, N.C.; Sutherland, S.; Gangi, L.J. 2006. FIREMON: Fire Effects Monitoring and Inventory System. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. <http://www.fs.fed.us/rm/pubs/rmrs_gtr164.html>.

Reinhardt, E.; Keane, R.E. 1998. FOFEM—A First Order Fire Effects Model. Fire Management Notes. 58: 25–28.

Reinhardt, E.; Keane, R.E.; Brown, J.K. 1997. First Order Fire Effects Model: FOFEM 4.0 user's guide. Gen.Tech. Rep. INT-GTR-344. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 7 p.

Scott, J.H. 1999. NEXUS: A system for assessing crown fire hazard. Fire Management Notes. 59: 21–24.