

ArcFuels: Forest Planning Tools for Managing Wildland Fuels

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Abstract

Landscape analysis of wildland fuel treatment strategies on Federally-managed lands is a complex modeling problem that has received relatively little attention. A number of vegetation and wildfire behavior models are available (e.g., FVS, FVS-FFE, SVS, FARSITE, NEXUS, BEHAVE), but integration among models and the data they require is weak. Key questions concern the response of forest landscapes to fuel treatment in terms of forest structure, composition, fire behavior, visuals, etc. We developed a library of VBA macros ("ArcFuels") within ArcMap to link and drive a number of models that are useful for analyzing fuel treatment scenarios. We applied the system to a wildland urban interface in northeastern Oregon and examined a number of long-term (60-year) treatment strategies. The treatment strategies used spatial goals and constraints to explore how different management approaches affected potential fire behavior. The library of macros facilitates the analysis and visualization of forest management scenarios.

Introduction

Planning fuel treatment projects on large forested landscapes requires a number of wildfire and vegetation models to simulate and test the merits of proposed management (Finney and Cohen 2002). Treatment scenarios are typically constructed by iteratively selecting stands for treatment, and subsequently evaluating the aggregate effects of treatments on landscape-scale wildfire behavior using wildfire simulators. Ideally, the selection of specific stands is based on both the potential fire behavior within the stand, and the stand's topological relationship to other treated stands (Finney 2004). Stand simulation models are used to design and test stand-specific fuel treatments that reduce excessive crown, ladder, and surface fuels (Keyes and O'Hara 2002, Pollet and Omi 2002, Scott 2003, Fule et al. 2001). Landscape fire simulation models are used to test whether the treatment topology is effective at slowing wildfire spread and reducing wildfire probabilities for the all or some key portion (i.e. urban interface) of the project area. Fuel treatment projects that do not address both stand and landscape aspects of the problem may be ineffective in terms of reducing the threat from large wildfires (Finney 2004, Finney and Cohen 2002). The process for designing fuel treatments is complicated by other management goals and constraints on public lands related to forest restoration, TES species, and NEPA regulations (Hayes et al. 2004).

The complexity of wildfire issues on diverse landscapes in the western USA issue has spawned many models for simulating forest management and wildfire behavior. However, integration among many of the models used in the planning process is weak, and data linkages between the models and the databases supported by land management agencies are not well developed. In this paper we describe ArcFuels, a library of VBA macros implemented within ArcMap for fuels treatment planning. Collectively, these macros integrate a number of models and data sources within a GIS-based interface to facilitate the analysis of fuels treatment issues on large landscapes over time.

Functionality for Fuels Treatment Planning

The selection of models and linkages within the ArcFuels interface was aimed at providing the user with the following key functionality for fuels treatment planning:

1. An interactive system within ArcMap to develop of stand-specific silvicultural prescriptions and fuel treatments, including thinning, underburning, and mechanical fuels treatment.
2. Automated generation of data plots showing how stand fuel treatments change wildfires in terms of flame length, fire behavior [surface or crown], and stand mortality over time.

3. Rapid scale-up of stand-specific treatments to simulate project-wide changes in vegetation and fuels from proposed management activities.
4. Tight data linkages to FLAMMAP or FARSITE to simulate landscape-scale fire behavior and measure the treatment performance in terms of wildfire probabilities, spread rates, and fireline intensity (Finney 2004).
5. Ability to easily modify and re-evaluate fuel treatment scenarios.

ArcFuels

The Arcfuels macros provide linkages among vegetation and wildfire behavior models and Forest Service vegetation databases within ArcMap (Table 1). The VBA code is implemented on two toolbars in ArcMap corresponding to stand and landscape modeling of fuels treatment and potential wildfire behavior. The functionality of the two toolbars is described below.

Stand level analysis

Stand level analysis is used to develop treatment prescriptions that reduce fuels while meeting other management goals. The Forest Vegetation Simulator (Dixon 2003) is typically used to simulate thinning, prescribed fire, and mechanical treatment of downed fuels, and the post-treatment potential fire behavior is examined with one or more fire models. The primary concern is the potential for crown fire activity, although other management goals and constraints can have a significant influence on the final prescription. These simulations use a well defined weather scenario, usually generated from field weather stations (<http://www.fs.fed.us/raws/>) using FireFamily Plus (USDA Forest Service 2002). Stand prescriptions are developed with a number of FVS keywords (e.g. THINSDI, SIMFIRE, FUELMOVE, see Dixon 2003). A significant portion of this work involves validating data, defining values for model parameters, and iteratively examining different treatment combinations. Models may also be used to examine the longer term (e.g. 50 years) effects of the treatments on forest density and dead fuel dynamics.

Stand level analysis is accomplished within ArcFuels using the *Stand Query* function. Users view digital ortho-photos of the project area in ArcMap and test different management prescriptions by clicking on specific stands. Clicking the stand executes one or more programs selected by the user. Typically, the identified stand is processed with Forest Vegetation Simulator to simulate management activities, forest growth, and potential wildfire behavior through time. FVS outputs are generated in spreadsheet format using the FVS database extension (Crookston and Gambel 2004) and VBA macros generate graphs of stand metrics, fuel loadings, and fire behavior through time. The FVS Fire and Fuels Extension can simulate fire and fire-related mortality at the stand level using the SIMFIRE keyword (Reinhardt and Crookston 2003, p. 66). Potential wildfire behavior at the stand level can be modeled with the POTFIRE keyword. The treatments and simulated wildfire can then be visualized through time using the stand visualization system (SVS, McGaughey 2002). A direct link on the toolbar to the FVS prescription keywords allow for rapid changing of management prescriptions and testing of different fuel treatment options. The *Stand Query* function also builds input files for Nexus (Scott 1999) for performing rapid sensitivity analysis of fire behavior under different weather conditions. Linkages are under development for My Fuels treatment Planner as well.

When high resolution (1:12000 color) photo mosaics are used as backdrops, the system provides a relatively rapid way to compare photographic images of stands with SVS outputs, and coarsely validate vegetation data. The system also allows for rapid verify the spatial accuracy of stand polygon delineations.

Landscape Modeling

Landscape analysis of fuel treatment scenarios examines the aggregate effect of all treatments on potential wildfire behavior. Of primary interest is the effect of the treatments on spread rate across the project area, and the intensity of the fires near urban interfaces. The effects of fuel treatments on other landscape-scale goals for wildlife, visuals, aquatics, and forest restoration may also be examined (Hayes et al. 2004). Of key importance is the spatial arrangement and

size of the fuel treatments relative to the direction of a likely wildfire event (Finney 2001). Observations from wildfires and results from wildfire simulators demonstrate shown that both the size and spatial arrangement of fuel treatments are strong determinants of wildfire spread rates (Finney 2004).

Testing the performance of landscape fuels treatment strategies can be accomplished with the FLAMMAP program (Table 1). A recently released version of FLAMMAP can model fire spread, travel time, and calculate wildfire probabilities (Finney, pers com.). ArcFuels macros facilitate preparing FLAMMAP inputs via the Parallel Processing Extension (FVS-PPE, Crookston and Stage 1991) and Fire and Fuels Extension (FVS-FFE, Crookston and Reinhardt 2003). Fuel treatment scenarios can be simulated with FVS-PPE using pre-determined treatment stands or dynamic stand priorities based on stand attributes. ArcFuels builds data input files for the FVS-PPE from MS Access vegetation databases (Crookston and Gammel 2004). Subsets of a landscape can be selected using the Select command in ArcMap, providing a simple method to interactively simulate spatial subunits or specific stand types. Database outputs can be automatically joined to stand polygon coverages for rapid viewing of results. To build the FARSITE and FLAMMAP landscape files FVS-PPE outputs are converted to ASCII GRID format and then processed with LCPMAKE.EXE¹ to build binary landscape files. This process generates landscape files for each cycle in a simulation (e.g. 10 year period).

A challenging part of building and testing fuel treatment scenarios is replicating the matrix of policy constraints and management goals on large multi-owner forested watersheds. ArcFuels uses a database approach to organizing management prescriptions for stands within a project area, and codes prescriptions within the stand database required by FVS (Crookston and Gammel 2004). Key information about land management strata and other factors important for building management scenarios (e.g. ownership, management emphasis) are also added to the stand database. Fields in the database are created for each scenario, with the records containing an alphanumeric code that corresponds to a text file containing FVS keywords for that prescription. Scenarios are built with database queries that code prescriptions based on other attributes in the database. VBA macros read scenario information and generate FVS-PPE input files at runtime.

Summary and Future Work

The ArcFuels macros address a major gap in the integration of tools for modeling fire and fuels. We are continuing to develop ArcFuels and streamline the application of fire behavior and vegetation models to address wildfire risk and fuels management problems in the western USA. Eventually the macros will be incorporated into an ArcMap extension.

Table 1. Vegetation and fire models used in ArcFuels

Model (Abbreviation)	Modeling Function	Reference and Download
Forest Vegetation Simulator (FVS)	Stand dynamics and management	Dixon 2003 www.fs.fed.us/fmsc/fvs/software/index.php
Fire and Fuels Extension (FVS-FFE)	Potential fire behavior, prescribed burning, mechanical fuels treatments, dead wood dynamics	Crookston and Reinhardt 2003 www.fs.fed.us/fmsc/fvs/software/index.php
Parallel	Landscape extension to	Crookston and Stage 1991

¹ LCPMAKE is available from Mark Finney, mfinney@fs.fed.us

Processing Extension (FVS-PPE)	FVS	www.fs.fed.us/fmssc/fvs/software/index.php
FVS Database Extension	FVS database input and output	Crookston and Gamble 2003 www.fs.fed.us/fmssc/fvs/software/index.php
Stand Visualization System (SVS)	Stand visualization of growth, treatments, and stand wildfire behavior	McGaughey 2002 forsys.cfr.washington.edu/svs.html
FARSITE	Landscape fire behavior	Finney 1998 www.fire.org
FLAMMAP	Landscape fire behavior	Finney unpublished www.fire.org
Nexus ¹	Stand fire behavior	Scott 1999 www.fire.org
MYFTP ¹	Stand fuels treatment planning	www.fs.fed.us/pnw/data/myftp/myftp_home.htm

¹ Linkage under development at this time.

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