

Using ArcObjects for Automating Fireshed Assessments and Analyzing Wildfire Risk

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Abstract

Firesheds are geographic units used by the Forest Service to delineate areas with similar fire regimes, fire history, and wildland fire risk issues. A Fireshed assessment is a collaborative process where specialists design fuel treatments to mitigate wildfire risk. Fireshed assessments are an iterative process where fuel treatments are proposed for specific stands based on potential fire behaviour and the resulting matrix of treatments is evaluated in terms of reducing landscape scale fire spread. The Fireshed process uses an array of fire behavior models and GIS operations, making it difficult to analyze large numbers of scenarios in a timely fashion. We automated Fireshed analysis with Visual Basic macros and ArcObjects. The macros are implemented on custom toolbars in ArcMap, and link vegetation and wildfire behaviour models with ArcGIS, desktop office software, and Forest Service vegetation databases, providing the capability for real-time evaluation of proposed fuel treatments within ArcGIS.

Introduction

Widespread fuel reduction programs have been initiated in many parts of the USA in response to a growing threat of wildland fire (USDA 2003, 2004). Urban encroachment, fire suppression policies, and drought all have been linked to increasing wildfire severity. Developing wildfire mitigation strategies is a challenging problem, especially on federal wildlands where land management regulations, cost, and public expectations make it difficult to implement large-scale fuel treatments needed to reduce the incidence of extreme wildfires (Finney and Cohen 2002). State of the art wildfire modeling is frequently required to demonstrate the benefits of fuels reduction treatments and defend fuels management projects.

In 2004 we initiated a project funded by the Joint Fire Science Program (www.nifc.gov) to streamline wildfire modeling for fuels management projects (Ager and McGaughey 2003). In the first phase of this project we developed a library of macros using ArcObjects to integrate wildfire models and vegetation databases within ArcGIS. The macros automated much of the data organization and modeling required in the Fireshed process (Bahro et al. 2006), and the development of spatially optimized treatments (SPOTS, (<http://www.nifc.gov/spots/>)). The second phase of the project involved testing the macros on several study areas, and led to an actuarial approach for quantifying wildfire risk and measuring the effectiveness of fuel treatments in landscape fuels projects (Finney 2005). In this paper we describe our work to integrate the Fireshed process and risk assessment methods into ArcGIS.

Fireshed Assessments

The Fireshed assessment process was created by a cadre of specialists with the Forest Service Region 5 (California) as a means for designing landscape fuel treatments in a collaborative, interactive setting (Amboy 2006; Bahro 2004; Bahro et al. 2006). The Fireshed process begins with the delineation of geographic units (10,000 to 50,000 ha) with similar fire regimes, fire history, and wildfire risk issues. In real time, fuel treatments are located on digital maps with input from land managers and landowners, and then tested with wildfire simulation models to examine their effect of wildfire spread and intensity. Each stand prescription is designed address crown, ladder, and surface fuels, as well as other resource management goals such as wildlife habitat or scenic considerations. Initial treatment locations are guided

by spatial optimization that locates treatments to minimize wildfire travel time (Finney 2004). The collection of stand prescriptions is then examined on a landscape basis to assess the overall effect of fuel treatments. Fuel treatment projects that do not address both stand and landscape aspects of wildfire behaviour may not mitigate the threat from severe wildfires.

The Fireshed process is a means to build consensus among landowners and concerned publics about wildfire issues and mitigation strategies. By providing an interactive forum to simulate and test fuel treatment strategies, the Fireshed solution finds a balance among multiple and often competing resource objectives and landowner needs. The Fireshed process and general framework is increasingly being used as an organizing and operational framework for landscape fuel treatment planning (Gallagher 2005 McDaniel 2006). The Fireshed process was recently adopted nationally by the Forest Service as part of the Stewardship and Fireshed Assessment Pilot Program (Gercke and Stewart 2006).

ArcFuels

A major difficulty in the Fireshed assessment process has been the lack of data integration among fire behaviour models, and weak linkages to GIS, Forest Service data, and desktop office software. Designing and testing fuels treatment scenarios is a complex, data intensive process, and many metrics, including fire spread, intensity, expected loss, and other ecological risks must be analyzed. Some aspects of the Fireshed process were streamlined with Arc AML's (Amboy 2006). We have since created "ArcFuels", a more comprehensive approach for integrating data and fire models within ArcGIS through the use of ArcObjects (Chang 2004) and Visual Basic for Applications (VBA, Pattison 1998). ArcFuels macros link vegetation and wildfire behaviour models with MS-Access, Excel, and Forest Service vegetation databases, greatly improving the capability for real-time evaluation of proposed fuel treatments within ArcGIS.

ArcFuels was specifically designed to provide the following functionalities: (1) an interactive system within ArcMap to simulate stand-specific silvicultural prescriptions and fuel treatments, including thinning, under-burning, and mechanical fuels disposal; (2) an automated generation of data plots showing how individual fuel treatments change wildfires in terms of flame length, fire behaviour [surface or crown], and stand mortality; (3) a rapid scale-up of stand-specific treatments to simulate landscape change in vegetation and fuels; (4) data linkages to FlamMap (www.fire.org) and FARSITE (Finney 1998) to simulate landscape-scale fire behaviour, and measure the treatment performance in terms of wildfire probabilities, spread rates, and fire line intensity (Finney 2004); (5) ability to easily modify and re-simulate fuel treatment scenarios; and (6) rapid mapping of wildfire behaviour model outputs in ArcMap.

Modeling Stand Fuel Treatments

Fuels planners and silviculturists model treatment units to develop and test prescriptions that meet objectives for specific stand density, species composition, and post-treatment potential fire behaviour. Prescriptions are modeled in the Forest Vegetation Simulator (FVS) (Dixon 2003) and the FVS Fire and Fuels Extension (FVS-FFE, Reinhardt and Crookston 2003), and typically include thinning, prescribed fire, and mechanical treatment of surface fuels. Pre- and post-treatment fire behaviour is examined for specific weather scenarios developed from historical weather data (<http://www.fs.fed.us/raws/>). The FireFamily Plus program (Bradshaw and McCormick 2000). facilitates the development of weather scenarios.

ArcFuels provides interactive linkages to FVS and FVS-FFE via a stand query function that allow users to interact with stand data and fire models. Users can also load digital color imagery for their project area (<http://www.apfo.usda.gov/NAIP.html>) and overlay treatment polygon layers, and then test different

management prescriptions by clicking on specific stands to execute one or more fire models. For instance, clicking on a stand polygon will (1) simulate management activities and potential wildfire within FVS; (2) generate Excel graphs of stand metrics, fuel loadings, and fire behaviour, and; (3) display the stand in the Stand Visualization System (SVS, McGaughey 2002). A direct link on the ArcFuels forms to FVS prescription keywords allow for rapid changing of management prescriptions, and testing of different fuel treatment options. The system provides a rapid method for browsing a landscape in a spatial context, examining and visually validating the data representing the stand, and iteratively testing stand-level treatment prescriptions within a GIS.

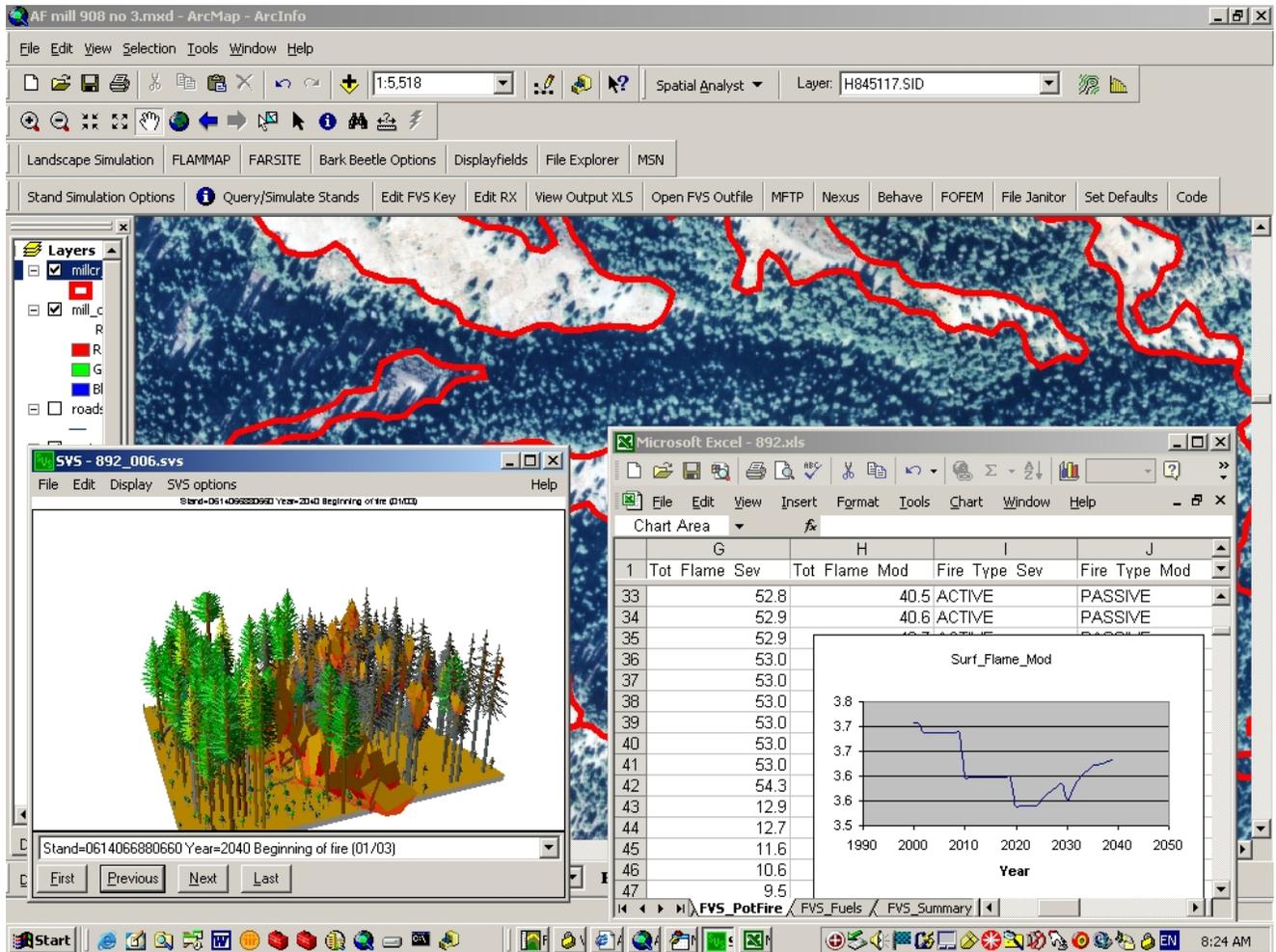


Figure 1. ArcFuels interface showing the use of the stand query function was to select a stand and process the stand data with FVS to simulate a wildfire. The FVS outputs are automatically loaded into SVS (left panel), and graphed with Excel (right panel).

Landscape Modeling

ArcFuels automates the process of scaling up individual stand prescriptions to a Fireshed and simulating the landscape package of treatments with wildfire simulation models. The assignment of treatments to stands is accomplished in six ways: (1) attribute selection query in ArcMap, (2) ArcFuels stand query function; (3) database queries that key off data in the stand database, (4) treatment optimization asciigrid from FlamMap, (5) dynamic selection with the FVS-PPE *Priority* variable (Crookston and Stage 1991), and (6) external programs linked to FVS-PPE .

ArcFuels uses a database approach to organize management prescriptions for stands within a project area, and codes prescriptions within the stand database used by FVS (Crookston et al. 2006). This simplifies the process of replicating complex constraints and management goals for multi-owner Firesheds.

Once prescriptions have been assigned to all of the treatment units, landscapes are processed with FVS or FVS-PPE (Parallel Processing Extension, Crookston and Stage 1991), depending on the problem. ArcFuels macros can be used to convert FVS database outputs to the binary landscape files required by FlamMap and FARSITE. This system can be used to generate sets of landscape files for multi-period and multi-scenario FVS simulations. FVS database outputs can be automatically joined to stand coverages for rapid mapping of the simulation outputs. FlamMap ascii-grid outputs can also be imported to grids using the ArcFuels interface (Figure 2).

We also wrote macros in ArcFuels for processing Landfire grid data (www.landfire.gov). These data are available many parts of the USA and include all the spatial layers for running FlamMap and FARSITE. Landfire-grid data can be converted to the FlamMap binary landscape files using a process that allows the user to adjust the grid data for fuel treatments using stand-specific information stored in a database. The adjustment system allows for pixel-level [versus entire stand] manipulation of the Landfire grid data, and for a single stand to receive different treatments. Treatments can also be applied by using a FlamMap treatment optimization grid.

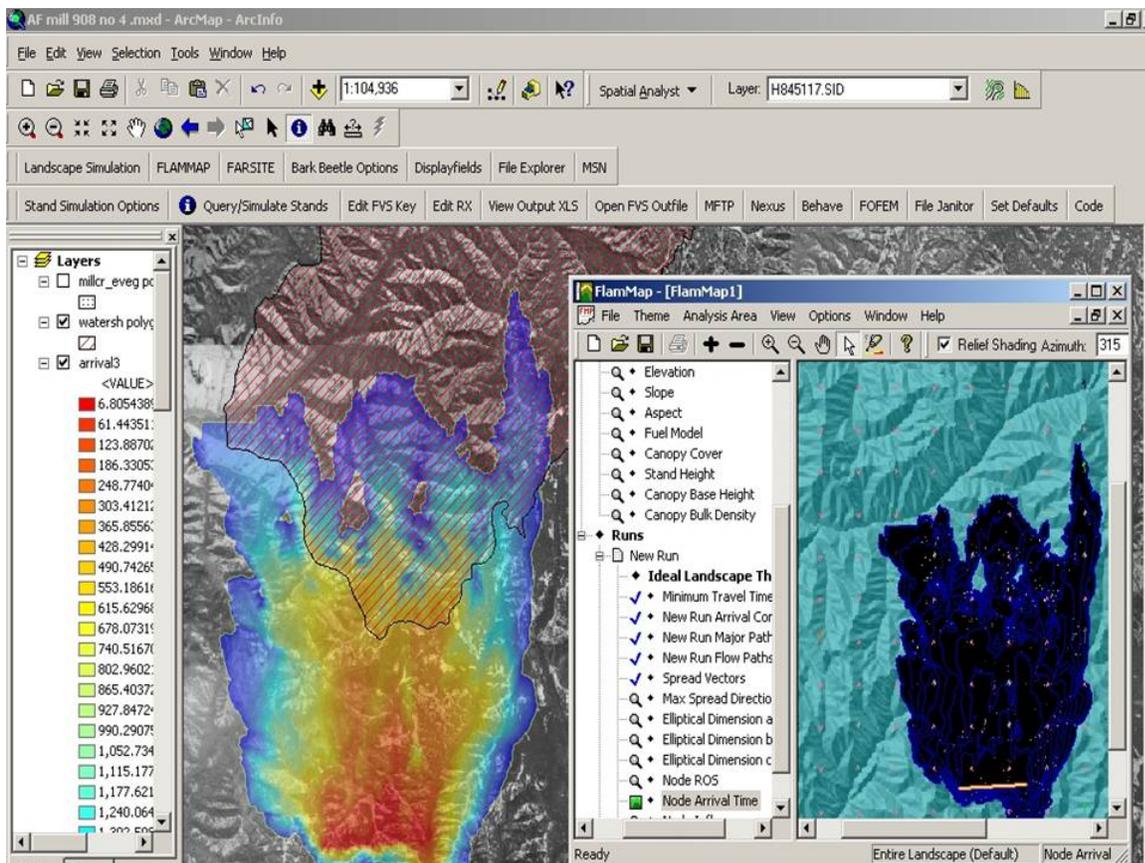


Figure 2. ArcFuels can be used to simulate landscape management alternatives and build a FLAMMAP landscape file. Right panel shows a FlamMap run for the Mill Creek watershed, Umatilla National Forest. The fire arrival time from FlamMap is imported and displayed in ArcMap on the left.

Wildfire Risk Assessment

Fireshed assessments and other fuel treatment projects have led to an active debate about measuring the potential effectiveness of fuel treatments in terms of mitigating wildfire risk. The printed and online literature contains many examples of wildfire risk assessments. However, very few of these attempt to include interactions among wildfire spread, intensity, and effects on the value of resources.

In an effort to enhance risk assessment methods within the Fireshed process, we adopted an actuarial formulation of wildfire risk as the *expected net value change* (ENVC) calculated as the product of (1) probability of a fire at a specific intensity and location, and (2) the resulting change in financial or ecological value (e.g. Bachmann and Allgöwer 2001; Brillinger 2003; Finney 2005). Expected net value change can include present, future, positive, and negative impacts from wildfire. We modified existing programs (Finney 2005) to calculate ENVC for a hypothetical fuel treatment scenario. The study area was the Mt. Emily wildland urban interface, which extends 30 km along a north-south ridge immediately north of La Grande, Oregon. We used a three step modeling process that involved (1) simulating landscape fuel treatment scenarios with the Forest Vegetation Simulator linked to the Parallel Processing Extension; (2) calculating fire spread parameters with FlamMap, and (3) simulating random fires and net value change with the fire spread program RANDIG (M. Finney, unpublished). Steps 1 and 2 were accomplished with ArcFuels macros, and step three involved batch processing landscapes with the RANDIG program. The example is part of a larger study reported elsewhere (Ager et al. in press).

We simulated treating 20% of the forested area, and selected stands based on residential density. Residential density (residences/km²) was calculated from a point layer of homes obtained from the Oregon Department of Forestry using a kernel density estimator with a 2 km search radius. Each stand polygon was assigned the average residential density of the pixels within the polygon. Only stands that exceeded stand density thresholds were eligible for treatments. Simulated fuels treatment prescription consisted of selective thinning, site removal of surface fuels, and under-burning.

To calculate burn probabilities for the ENVC equation, we simulated 200 random wildfires with RANDIG. The duration of each fire was determined using a Monte Carlo approach that sampled a frequency distribution of spread event days developed from a database of recorded fires on the Umatilla National Forest from 1970 to 2005 (data on file, Umatilla National Forest). Using the definition of risk as the expected net value change, we incorporated risk calculations into the RANDIG program with the following process. We assigned a fixed value of \$200,000 to each of the 176 homes in the WUI and then smoothed the point data using a kernel density function with a search radius of 200 m to generate a smooth grid of home values. The goal was to represent the value of individual homes on a number of pixels to reflect the uncertainty in the modeling about loss from direct ignition, and the fact that significant value in the rural residences exists around the main structure. Each residence was represented by 125 pixels having a maximum and minimum value of about \$200 and \$8,000 respectively. A loss function was then created by assuming a linear damage with increasing flame length. This loss function is purely hypothetical and was created solely to demonstrate the calculation of ENVC.

The results of the simulation showed a decrease of about 38% in the average pixel burn probability after treating 20% of the forested area compared to a no treatment scenario. Expected net value increased 50% from the treatments (-\$38.4/ha to -\$19.1/ha). The change in net value varied widely around individual homes due to spatial effects of individual treatments in relation to homes (Figure 3). Some residences were relatively unaffected by the treatments, i.e. losses were not reduced by fuel treatment, while other residences showed a large increase in net value.



Figure 3. Change in expected net value for a hypothetical wildfire risk assessment on a portion of the Mt. Emily wildland interface. Black points are residences. The value of each residence was proportioned to the surrounding 200 meter pixels using a density smoother. Fuel treatments are represented by yellow hatching. Color shading around homes indicates the change in loss between no treatment and treating 20% of the study area. Red shade indicates no different between treated and untreated areas in expected loss from wildfire. Green shades indicate about 50% reduction in loss. Wind direction was 240 degrees azimuth. The simulation used a hypothetical loss function that assumed a linear loss with increasing flame length.

Discussion and Conclusion

Our application of ArcObjects and VBA macros facilitates Fireshed and wildfire risk assessments. The macros link spatial data to wildfire models like FlamMap and FVS-FFE, and provide an interactive modeling and mapping environment within ArcGIS. ArcFuels macros are designed for field level application and are compatible with Forest Service vegetation data formats. The system facilitates the real time modeling of fuel treatment scenarios in Fireshed and similar landscape analysis projects, where many fuel treatment alternatives are simulated to find the most effective treatment arrangement.

The risk analysis illustrated the use of expected net value to measure the effects of fuel treatments. The risk framework incorporates wildfire spread and intensity, and thus considers both stand and landscape scale wildfire behaviour. This approach offers a more robust measure of wildfire risk compared to many other wildfire risk assessment procedures that only consider localized stand scale fire behaviour. The risk framework can be applied to analyze long-term risk tradeoff between wildland fire benefits and the cost of wildfire suppression and fuels treatments (Calkin and Hyde 2004, Calkin et al. 2005). Additional work on the risk assessment process is underway, including the analysis of how factors like ignition location, weather conditions, and the effectiveness of fire suppression affect burn probabilities. The risk framework described here can easily accommodate multiple loss and benefits (Rideout and Ziesler. 2005) to create integrated, probabilistic measures of wildfire risk.

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