Automating the Fireshed Assessment Process with ArcGIS

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***Abstract**—A library of macros was developed to automate the Fireshed process within ArcGIS. The macros link a number of vegetation simulation and wildfire behavior models (FVS, SVS, FARSITE, and FlamMap) with ESRI geodatabases, desktop software (Access, Excel), and ArcGIS. The macros provide for (1) an interactive linkage between digital imagery, vegetation data, FVS-FFE, and SVS, creating a map-based interface for designing and testing stand fuel treatments; (2) rapid scale-up of stand-specific treatments to simulate project-wide changes in vegetation and fuels; (3) data linkages between FVS outputs and FlamMap/FARSITE to allow for simulation of landscape-scale fire behavior and evaluation of fuel treatment scenarios; and (4) data linkages between FVS outputs and ArcMap for rapid mapping of FVS database outputs. The library is distributed as an ArcMap project file (.mxd) and is implemented on custom toolbars on the ArcMap interface. The system was designed to automate geospatial analyses performed in the Fireshed process to design and test fuel treatments in a collaborative setting. A beta version of ArcFuels is available from the senior author.*

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 activities (Finney and Cohen 2002; Stratton 2006). Treatment scenarios are typically constructed by iteratively selecting stands for treatment, and subsequently evaluating the aggregate effects of treatments on landscape-scale wildfire behavior by 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). 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 multiple management goals and constraints on public lands (Hayes and others 2004). A further, perhaps more challenging problem for federal land managers is that wildfire does not recognize land ownership boundaries, and thus treatments must be designed in collaboration with other landowners. To address these problems, a cadre of Forest Service fire specialists created a collaborative process for building multi-ownership fuel treatment plans (Amboy 2006; Bahro 2004; Bahro and others 2006). The process integrates multiple land and resource management objectives when addressing and evaluating fuel treatments (Ewell and others 2006). The "Fireshed" process starts with the delineation of geographic units (10,000 to 50,000 ha) with similar fire regimes, fire history, and wildland fire risk issues. In a collaborative setting, fuel treatments are designed and tested in near real time with wildfire simulation

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models (FARSITE, FlamMap). The process requires a number of support staff including geographic information system (GIS) specialists, database analysts, and fire modelers, as well as a library of GIS macros and other programs. The Fireshed process represents a major advance in fuel treatment planning, and led to the Stewardship and Fireshed Assessment Pilot Program in the Forest Service (Gercke and Stewart 2006). The framework is increasingly being used as an organizing and operational framework for landscape fuel treatment planning (Gallagher 2005). The concept of a fireshed also has ecological science value and is being used as a research framework (Jordana and others 2003).

In 2004, one of the authors (Ager) received funding from the Joint Fire Science Program to streamline the process of fuel treatment planning (Ager and McGaughey 2003). The project proposal identified a gap in the integration and data linkages among fire behavior models, vegetation and fuel data, GIS, and desktop software. The Fireshed process was adopted as the design template for the work. In this paper, we describe our progress to streamline and integrate fuel treatment planning and the Fireshed process, and a new library of macros (*ArcFuels*) within ArcGIS.

ArcFuels

Overview

We used the ArcObjects library (Chang 2004) and Visual Basic for Applications (VBA) (Pattison 1998) within ArcMap as the development framework. The VBA development interface is integrated within ArcMap and Microsoft (MS) Office products (Excel and Access); ArcFuels macros are distributed within ArcGIS project files (.mxd). The project file is loaded into ArcMap, and the macros appear as toolbars. Project defaults that specify the paths of installed fire behavior models, vegetation databases, GIS themes, and various other parameters are stored in a MS Access database.

The selection of models and linkages within the ArcFuels interface was aimed at providing the user with the following functionality for fuel treatment planning: (1) an interactive system within ArcMap to develop stand-specific silvicultural prescriptions and fuel treatments, including thinning, underburning, and mechanical fuel 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 fuel 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 reevaluate fuel treatment scenarios; and (6) integration of fire modeling spatial outputs into ArcGIS and other programs to facilitate the evaluation of fuel treatments with multi-resource objectives.

Data

Detailed modeling of fuel treatments for project-level planning requires tree list data and information on surface fuel loadings. Forest Service tree list data are stored within the FSVEG database system. In many projects, data for polygons without stand exams are imputed by using a most similar neighbor approach (Crookston and others 2002). The Forest Service FSVEG system can generate spatial vegetation databases that are compatible with the FVS database extension (Crookston and others 2006). For the Fireshed process, these databases can be augmented with key information about land management strata and other factors important for building management scenarios (for example ownership, management emphasis) and prescriptions.

Stand Modeling of Fuel Treatments

Developing and testing treatment prescriptions for specific stands is an iterative process that seeks to find the best prescription to meet multiple objectives. ArcFuels provides interactive linkages to the Forest Vegetation Simulator (FVS) (Dixon 2003) and the FVS Fire and Fuels Extension (FFE), which are widely used to simulate thinning, prescribed fire, and mechanical treatment of downed fuels, and the post-treatment potential fire behavior. These simulations use a well-defined weather scenario, usually generated from field weather stations (http://www.fs.fed.us/raws/) by using FireFamily Plus (Bradshaw and McCormick 2000). Stand prescriptions are developed with a number of FVS keywords (for example THINSDI, SIMFIRE, FUELMOVE, see Dixon 2003). FVS and FFE can also be used to examine the longer term (for example 50 years) effects of the treatments on forest density and dead fuel dynamics provided a forest regeneration model is available.

In the fuels treatment planning process, significant work is required to validate stand data, define values for model parameters, and design stand-specific treatments. To automate this process, we built a *stand query* function into ArcFuels to allow users to interact with stand data and fire models within the ArcMap interface. Users can also load digital color imagery for their project area (http://www.apfo.usda.gov/NAIP.html) and overlay stand polygon maps, and then test different management prescriptions by clicking on specific stands to execute one or more fire models. For instance, clicking on the stand within ArcMap can be used to: (1) simulate management activities and potential wildfire within FVS; (2) generate Excel graphs of stand metrics, fuel loadings, and fire behavior and; (3) Visualize treatments and wildfire effects in the Stand Visualization System (SVS, McGaughey 2002). A direct link on the ArcFuels forms to the 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.

Landscape Design and Testing of Fuel Treatments

Landscape analysis of fuel treatment scenarios examines the aggregate effect of all treatments on potential wildfire behavior. The effects of fuel treatments on other landscape-scale goals are measured at this stage. Goals for wildlife, visuals, aquatics, and forest restoration may also be examined (Hayes and others 2004). Of key importance is the spatial arrangement and size of the fuel treatments relative to the direction of a likely wildfire event. Testing the performance of fuel treatment strategies can be accomplished with the FlamMap program in terms of fire spread, travel time, and burn probabilities. The FVS parallel processing extension (Crookston and Stage 1991) is a key part of this system. FVS-PPE is a little used extension that recognizes stand contagion and can model harvest constraints, treatment goals, fuels, and generates many of the specific inputs needed by landscape fire models.

ArcFuels automates the process of selecting and/or assigning stand-specific prescriptions within a Fireshed and building the input files required by FlamMap. The assignment of treatments to stands is accomplished in six ways: (1) ArcGIS selection; (2) stand query function; (3) database queries that key off of data in the stand database; (4) importing a treatment optimization grid from FlamMap; (5) dynamic selection by using FVS-PPE variable; and (6) external algorithms. FVS-PPE can prioritize and constrain on multiple activities and land strata. The external algorithm approach was used by Finney (2004) for fuel treatment optimization.

ArcFuels builds scenario files for the FVS-PPE from MS Access vegetation databases (Crookston and others 2006). Subsets of a landscape can be selected by using the Select command in ArcMap, providing a simple method to interactively simulate landscape subunits or specific stand types (for example, select all stands within 200 meters of homes). FVS database outputs can be automatically joined to stand GIS coverages for rapid mapping of the simulation outputs. 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.

ArcFuels uses a database approach to organize management prescriptions for stands within a project area, and codes prescriptions within the stand database required by FVS (Crookston and others 2006). This simplifies the process of replicating complex constraints and management goals for multi-owner Firesheds. Key information about land management strata and other factors important for building management scenarios (for example, ownership, management emphasis) are stored in the FVS stand database.

Mapping Outputs

With the database extension, FVS outputs can be written to an Access database containing tables for stand summary statistics, potential fire behavior, fuels, and others (See Crookston and others 2006). A VBA script on the simulation interface joins these tables to the Arc feature class layer representing the stand polygons. Once joined, an array of map queries can be performed with ArcMap commands to analyze FVS outputs in a spatial context. The joining of other databases can be automated by editing the underlying VBA macro.

Summary and Future Work

Our work addresses a major gap in the integration of wildfire behavior models with GIS and desktop software used for the Fireshed process. The approach was made possible by the recent development and release of ESRI's ArcObjects, and integration of the Visual Basic development tools within ArcMap. The development strategy here permits rapid integration of new models within ArcGIS, and sharing of the VBA macros among other applications and projects. We are continuing to test ArcFuels in several Fireshed projects in the western United States. Further development is ongoing, including a system for modeling and manipulating grid-based fuel data (for example Landfire) for projects where tree-list type data are not available.

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