ArcFuels: An ArcMap Toolbar for Fuel Treatment Planning and Wildfire Risk Assessment

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Fire behavior modeling and geospatial analysis can provide tremendous insight to land managers in defining both the benefits and potential impacts of fuel treatments in the context of land management goals and public expectations. ArcFuels is a streamlined fuel management planning and wildfire risk assessment system that creates a trans-scale (stand to large landscape) interface for applying existing forest and fire behavior models within an ArcGIS® platform to design and test fuel treatment alternatives. ArcFuels does this through a custom toolbar designed for use with ArcMap® (see figure 1).

The ArcMap framework helps users incorporate data from a variety of sources to address issues that typify many fuel treatment projects. ArcFuels was built to accommodate both raster data (such as LANDFIRE data, available at <http://www.landfire.gov>) and forest inventory data to characterize fuels in the landscape. The structure of ArcFuels provides users with a logical flow from stand-to-landscape analysis of vegetation, fuel, and fire behavior using a number of existing models.

ArcFuels and Fuel Treatment Planning

ArcFuels adds a spatial context to the Forest Vegetation Simulator (FVS) (Crookston and Dixon 2005) and facilitates its application for both stand and landscape modeling of fuel treatments (see figure 2). All functionality and extensions available for use within FVS are available in ArcFuels, including the Fire and Fuels Extension (FFE-FVS) (Rebain 2010), which accesses a carbon model and a climate extension (Crookston and others 2010).

Much stand-level modeling involves validating data and iteratively examining different treatment combinations on individual stands or a suite of stands in a coordinated landscape fuel treatment strategy. The ArcFuels stand-level analysis using FFE-FVS typically involves simulating activities (such as thinning), as well as surface fuel treatments (such as pile burning, mastication, or broadcast burns), and examining the resulting changes to potential fire behavior and effects (such as tree mortality). Users can also apply the validation or assess-

Figure 1.—*ArcFuels10 toolbar.*

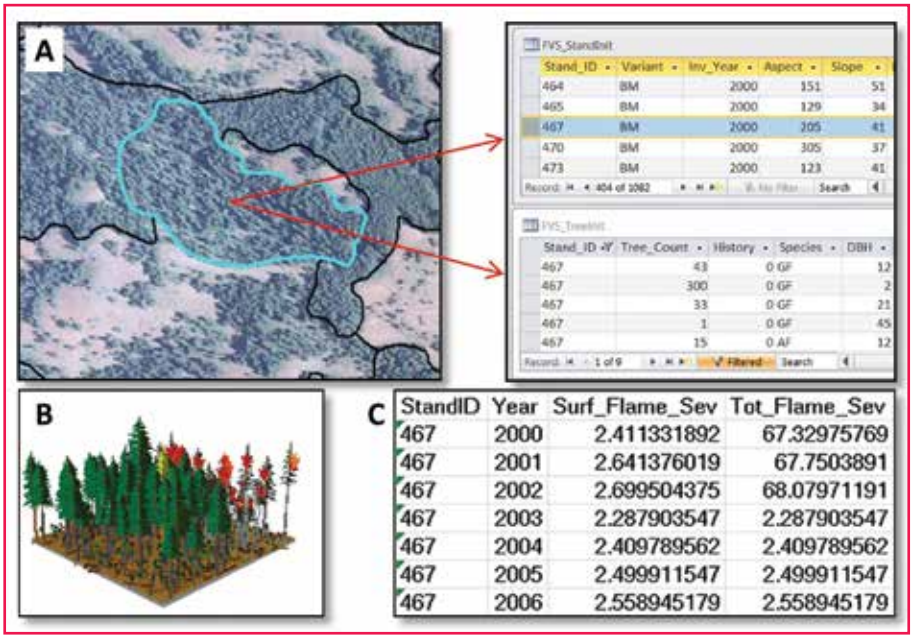

Figure 2.—*ArcFuels provides a way to spatially link a stand shapefile to FVS/FFE-FVS data (A) to run individual stands, select stands, or select an entire landscape. When running an individual stand, the user can run the stand visualization system to automatically visualize the FVS/FFE-FVS data (B), and FFVS/FFE-FVS outputs are automatically written to an Excel workbook. The surface and total flame length (in feet) for a simulated wildfire under severe conditions using FFE-FVS (C).*

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ment of fuel treatment prescriptions at the stand level to larger landscapes in developing landscape-level treatment alternatives.

At the landscape level, analysts typically use raster data or FFE-FVS outputs to build the input files for fire behavior modeling in FlamMap (Finney 2006). They can also use post-treatment stand development and fuel dynamics in FFE-FVS to determine retreatment frequency over time at both the stand and landscape levels.

Regardless of the fuel treatment plan, users can apply treatments to landscape data in two ways through ArcFuels: (1) by simulating all stands through FFE-FVS with treatment prescriptions, or (2) by altering raster data to represent post-treatment conditions by using appropriate stand-level FFE-FVS runs, monitoring data, or expert opinion to determine treatment adjustment factors.

ArcFuels and Fire Behavior Modeling

ArcFuels is linked to both stand-level and landscape-level fire behavior models. At the stand level, the user can complete fire behavior modeling within FFE-FVS through the ArcFuels interface and then export outputs in the format needed to run NEXUS (Scott 1999). ArcFuels has quick links to open both FOFEM (Reinhardt and others 1997) and BehavePlus (Heinsch and Andrews 2010) for external use, though it does not provide any inputs to those programs.

At the landscape level, ArcFuels contains links to open both FARSITE (Finney 1998) and FlamMap. Running FlamMap or FARSITE requires a landscape file (LCP), a binary file containing a compilation, or "sandwich," of geospatial data—including elevation, slope, aspect, fuel model, canopy cover, canopy height, canopy-base height, and canopy-bulk density—that characterizes the landscape.

The structure of ArcFuels provides users with a logical flow from stand-to-landscape analyses of vegetation, fuel, and fire behavior using a number of existing models.

ArcFuels streamlines the process of building LCPs from attributed shapefiles, raster data, or FVS/FFE-FVS output databases. Users can apply treatments rapidly through options in ArcFuels, outputting both raster files and LCPs. They can also use a suite of tools to postprocess outputs from FlamMap for further analysis in ArcMap. Once the fire behavior outputs are entered into ArcMap, users can assess fuel treatment performance in terms of changes to the types of fire, wildfire probabilities, spread rates, and fireline intensity (see figure 3).

ArcFuels and Wildfire Risk Assessments

Wildfire risk is the likelihood of a fire occurring, the associated fire behavior when a fire occurs, and the effects of the fire (Calkin and others 2010, Finney 2005, Scott 2006). A quantitative definition of fire risk includes fire behavior probabilities and fire effects for highly valued resources (HVRs) (see figure 4). Finney (2005) calls this quantitative definition "expected net value change (NVC)." The expected NVC can include financial, ecological, or other values at present day or future discounted values and can reflect both the positive and the negative impacts of fire.

Analysts can quantify fire effects through response functions that describe the impact of fire by flame length categories on HVRs or via FFE-FVS modeling, in which the effects are quantifiable (for example, the impact of flame length on tree survival). When wildfire benefits are not considered, expected NVC can be simplified as expected loss (EL). Using outputs from FlamMap5 and other geospatial data on HVRs, ArcFuels streamlines the calculation and processing of risk metrics, such as NVC, EL, and conditional flame length.

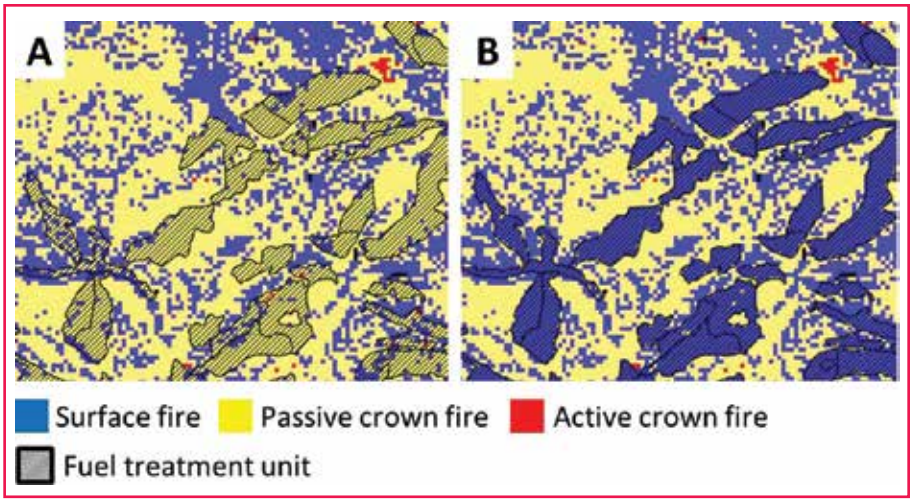

Figure 3.—*Maps of crown fire potential before (A) and after (B) fuel treatments as predicted with FlamMap.*

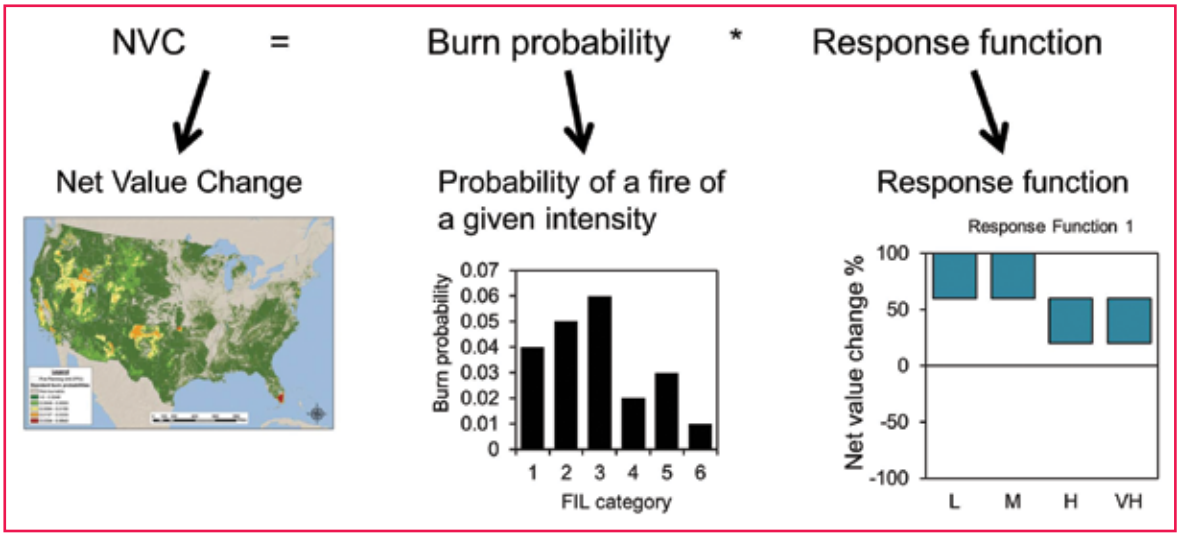

Figure 4.— *Calculating net value change for a single highly valued resource. Burn probability describes the probability of a fire for a given intensity, and the response function describes the change in the value at that intensity.*

Downloading ArcFuels

ArcFuels is available for both ArcGIS 9 and ArcGIS10 as ArcFuels9 and ArcFuels10. The primary difference between the versions is that ArcFuels10 includes wildfire risk assessment tools. Other minor differences exist between the functionality of ArcFuels9 and ArcFuels10. Please visit the Web site, <http://www.fs.fed.us/wwetac/arcfuels/>, to download ArcFuels, linked programs, supporting documentation and tutorials, and demonstration data. For more information about ArcFuels, contact Nicole Vaillant at <nvaillant@fs.fed.us>.

References

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

Crookston, N.L.; Rehfeldt, G.E.; Dixon, G.E.; Weiskittel, A.R. 2010. Addressing climate change in the forest vegetation simulator to assess impacts on landscape forest dynamics. Forest Ecology and Management. 260: 1198–1211.

Crookston, N.L; Dixon, G.E. 2005. The forest vegetation simulator: A review of its structure, content, and applications. Computers and Electronics in Agriculture. 49: 60–80.

Finney, M.A. 1998. FARSITE: Fire area simulator-model development and evaluation. Research Paper RMRS-RP-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 p.

Finney, M.A. 2005. The challenge of quantitative risk assessment for wildland fire. Forest Ecology and Management. 211: 97–108.

Finney, M.A. 2006. An overview of FlamMap fire modeling capabilities. In: Andrews, P.L.; Butler, B.W. (comps.) Fuels management—how to measure success: Conference proceedings. RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 213–220.

Heinsch, F.A.; Andrews, P.L. 2010. BehavePlus fire modeling system, version 5.0: Design and features. RMRS-GTR-249. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 111 p.

Rebain, S.A., comp. 2010. Revised July 2012. The fire and fuels extension to the forest vegetation simulator: Updated model documentation. Internal report. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Management Service Center. 408 p. <http://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/FFEguide.pdf>. (28 March 2014).

Reinhardt, E.D.; Keane R.E.; Brown J.K. 1997. First order fire effects model: FOFEM 4.0 user's guide. INT-GTTR-344. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 65 p.

Scott, J.H. 1999. NEXUS: A system for assessing crown fire hazard. Fire Management Notes. 59(2): 21–24.

Scott, J.H. 2006. An analytical framework for quantifying wildland fire risk and treatment benefit. In: Andrews, P.L.; Butler, B.W., comps. Fuels management—how to measure success: Conference proceedings. RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 169–184.

ArcFuels Publications

Vaillant, N.M.; Ager, A.A.; Anderson, J. 2013. ArcFuels10 system overview. PNW-GTR-875. Portland, OR: United States Department of Agriculture, Forest Service, Pacific Northwest Research Station. 65 p.

Vaillant, N.M.; Ager, A.A.; Anderson, J.; Miller L. 2013. ArcFuels user guide and tutorial: for use with ArcGIS 9®. PNW-GTR-877. Portland, OR: United States Department of Agriculture, Forest Service, Pacific Northwest Research Station. 256 p.

Ager, A.A.; Vaillant, N.M.; Finney, M.A. 2011. Integrating fire behavior models and geospatial analysis for wildland fire risk assessment and fuel management planning. Journal of Combustion. Article ID 572452. 19 p.