FARSITE—A Program for Fire Growth Simulation

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Fire growth simulation is the modeling of fire spread and behavior across landscapes with heterogeneous fuels, weather, and topography. There are numerous uses for fire growth simulation, including planning for potential wildland fires, prioritizing and locating fuel treatments, tactical support on active fires, and fire incident reconstruction.

The FARSITE Fire Area Simulator is a computer program designed to simulate fire growth using existing models of fire behavior found in the BEHAVE Fire Behavior Prediction and Fuel Modeling System (Andrews 1986) and in the Canadian Forest Fire Behavior Prediction System (Forestry Canada Fire Danger Group 1992). Because FARSITE can generate spatial maps of fire behavior, it is useful for producing detailed analyses of fire behavior and fire effects on geographic information systems (GIS's) (fig. 1). However, this modeling capability requires digital maps of terrain and fuels in GIS formats, which is the main limitation for users who want to do simulations.

Nevertheless, FARSITE is widely used by State and Federal agencies as well as private parties in the United States, who recognize the value of having GIS-based data on fuels and vegetation for a variety of applications. A national, interagency training course has been developed for FARSITE application and operation. Other special-purpose workshops are also taught. This article summarizes the uses, capabilities, data requirements, and training needed for FARSITE and identifies new features planned for a future release.

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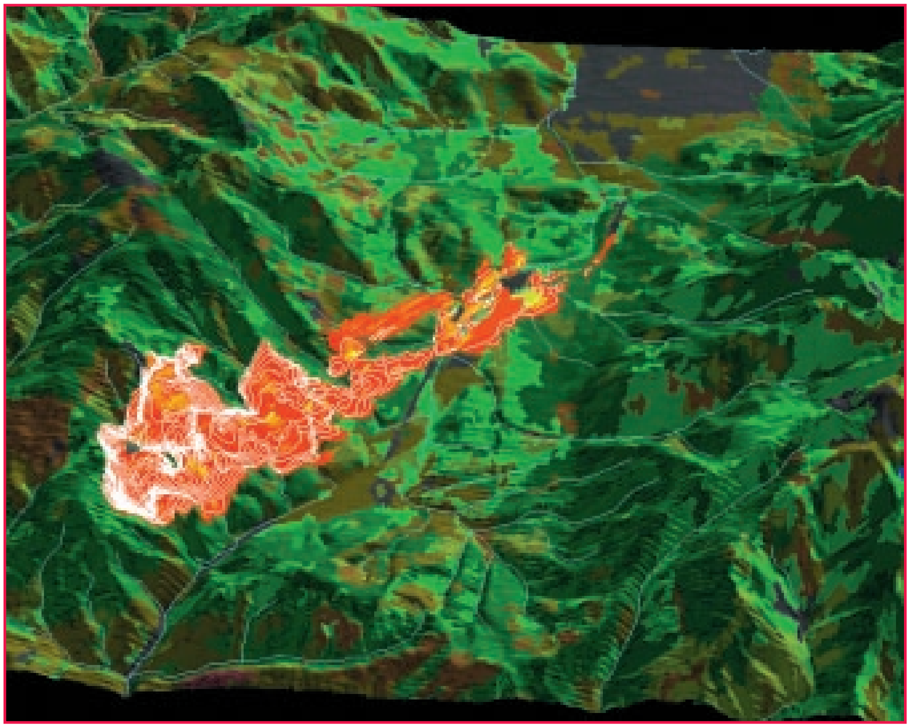

***Figure 1**—A FARSITE display using ArcView 3.0 to show fire intensity and perimeter output. FARSITE's spatial maps of fire behavior can help produce detailed analyses of fire behavior and fire effects.*

Uses

FARSITE has three main uses:

- Simulation of past fires,
- Simulation of active fires, and
- Simulation of potential fires.

Analysis of past fires reveals how well the simulation reproduces known fire growth patterns, given available input data. Simulating past fires is critical in developing confidence for using FARSITE to project the growth of active fires.

FARSITE was originally developed for long-range projection of active prescribed fires, generally on national parks or wilderness areas (Finney 1994). Simulations of active fires are run for general long-range weather scenarios to suggest possible outcomes of fire growth over many weeks. Potential fire growth is examined under various weather patterns, such as

> Currently, the most common use of FARSITE is to support fire planning by simulating potential fires at various locations under a variety of fuel and weather conditions.

persistence of current conditions or periodic frontal passage. A similar procedure using manual methods was reported by Mutch (1998) and Rothermel (1998). Recently, FARSITE has also been used for short-range (1- to 2-day) projections on large wildfires, where simulation results are used to support strategic firefighting decisions. If only part of the fire perimeter is of immediate interest, FARSITE can be used to simulate partial sections of the fire front. This application of FARSITE is similar to manual methods described by Rothermel (1983).

Fire planning is an appropriate use of FARSITE and currently its most common application. A potential fire can be simulated at various locations under a variety of fuel and weather conditions. Fire planning activities include, for example, analyzing spatial fuel management alternatives and examining suppression opportunities for fires that start in different locations or under various weather scenarios. Finney et al. (in press) used FARSITE to examine the economic consequences of potential wildfires occurring with and without fuel management activities.

Capabilities

The fire behavior models currently included in FARSITE calculate surface fire behavior, crown fire behavior, fire acceleration, spotting from torching trees, and fuel moisture (Finney 1998). The surface fire model (Rothermel 1972) is linked to the Van Wagner (1977; 1993) crown fire criteria to simulate transition to crowning and to the Rothermel (1991) crown fire spread correlation model. Spotting distance is simulated using the torching tree model by Albini (1979). Buildup of fire spread rate over time and with changes in environmental conditions is simulated using the point-source fire acceleration model of the Canadian Forest Fire Behavior Prediction System (Forestry Canada Fire Danger Group 1992; McAlpine and Wakimoto 1991).

FARSITE produces maps of fire growth (perimeter positions) and fire behavior in data formats that are suitable for ARC/INFO, ArcView, and GRASS GIS's. Most fire perimeter data are in vector format showing time contours of fire position. Vectors can be produced in ASCII as well as ArcView Shapefile formats. Raster maps can also be produced to show frontal fire behavior at each cell within the fire area. Fire behavior maps can be used for analyses of fire effects or for estimating suppression options.

Fire suppression can be simulated in FARSITE using several ground attack tactics as well as aerial attack. Ground tactics include direct, indirect, and parallel attack. Direct attack follows the immediate edge of the fire front using data on fireline production rate according to fuel and crew type. Indirect attack builds impermeable fireline along a predetermined route. Parallel attack, like direct attack, builds fireline at a specified constant distance from the moving fire front. The air attack features currently allow the user to place retardant drops by coverage level (retardant density) for a given aircraft (George 1992).

Data Requirements

Data required for FARSITE simulations make up the three legs of the fire environment triangle: fuel, weather, and topography. Fuel and topography are required as spatial themes, whereas weather data are generally provided as a "stream" or table of values over time. The spatial data must come from a GIS. GRASS and ARC/INFO ASCII raster data formats are accepted. Currently, spatial data for eight variables are used in FARSITE: elevation, slope, aspect, surface fuel model (Anderson 1982), canopy cover, canopy height, crown base height, and crown bulk density.

Weather data are divided into two files: one contains temperature, humidity, and precipitation data used for calculating changes in dead fuel moisture; the other contains wind and cloud cover data. The source for these data depends on the FARSITE application. Analysis of past fires is based on observed weather records. Short-range simulation of active fires requires the user to translate specific fire weather forecast information into the proper data format. Long-range simulation of active fires requires weather that goes beyond the period for which weather can be forecasted. Weather scenarios can be developed from summaries of nearby Remote Automatic Weather Stations over several years and percentile weather variables. Fire simulation for planning applications can use local weather and wind data to define typical or extreme weather patterns.

The fire suppression module of FARSITE requires the user to have estimates of fireline production rates in local fuel types for actual crews and crew types, as well as knowledge of the capabilities of available aerial firefighting resources.

Training and Implementation

Learning how to run the FARSITE program is different from learning how to define inputs and properly interpret the results. A fire behavior analyst uses FARSITE to simulate the growth of an active fire to support decisionmaking on wildfires and prescribed fires where lives and property might be at stake. The analyst is required to successfully complete the newly developed FARSITE Fire Growth Simulation (S–493) course and its prerequisites, and also to have a firm foundation of on-the-ground fire experience. The S–493 course provides a thorough understanding of the technical workings of FARSITE, including its limitations, so that the user can make the required judgment calls that must be made in simulating an active fire.

Other, less formal training sessions and workshops have been offered to meet specific needs. Less training is needed if a person is using FARSITE for educational purposes or exploring the interactions among components of fire and environment. Overview presentations have been offered to those who are interested in learning the range of possible uses of FARSITE.

Future Developments

Improvements to FARSITE are likely in the next several years. Better models for fire behavior will probably be substituted when they become available. Specifically, the current fuel moisture model will be replaced. Also, FARSITE will be modified to simulate general postfrontal combustion. This will allow smoke and heat from a fire to be calculated behind the flaming front. The results will be useful as input into separate atmospheric models used for estimating smoke dispersion.

The status of FARSITE and the most recent version of the program can be found on the Internet at <**http://fire.org**>.

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Literature Cited

Albini, F.A. 1979. Spot fire distance from burning trees—A predictive model. Gen. Tech. Rep. INT–56. Ogden, UT: USDA Forest Service, Intermountain Research Station. 73 p.

Anderson, H.E. 1982. Aids to determining fuel models for estimating fire behavior. Gen. Tech. Rep. INT–122. Ogden, UT: USDA Forest Service, Intermountain Research Station. 22 p.

Andrews, P.L. 1986. BEHAVE: Fire behavior prediction and fuel modeling system—BURN subsystem, part 1. Gen. Tech. Rep. INT–194. Ogden, UT: USDA Forest Service, Intermountain Research Station. 130 p.

Finney, M.A. 1994. Modeling the spread and behavior of prescribed natural fires. In: Proceedings of the 12th Conference on Fire and Forest Meteorology; 1993 October 26–28; Jekyll Island, GA. Bethesda, MD: Society of American Foresters: 138–143.

Finney, M.A. 1998. FARSITE: Fire Area Simulator—Model development and evaluation. Res. Pap. RMRS–RP–4. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. 47 p.

Finney, M.A.; Sapsis, D.B.; Bahro, B. In press. Use of FARSITE for simulating fire suppression and analysis of fuel treatment economics. In: Proceedings of Fire in California Ecosystems; 1997 November 17–20; San Diego, CA. USDA Forest Service, Pacific Southwest Research Station.

Forestry Canada Fire Danger Group. 1992. Development and structure of the Canadian Forest Fire Behavior Prediction System. Inf. Rep. ST–X–3. Ottawa, Canada: Forestry Canada Science and Sustainable Development Directorate. 63 p.

George, C.W. 1992. Improving the performance of fire retardant delivery systems on fixed-wing aircraft. Res. Note INT–400. Ogden, UT: USDA Forest Service. 12 p.

McAlpine, R.S.; Wakimoto, R.H. 1991. The acceleration of fire from point source to equilibrium spread. Forest Science. 37(5): 1314–1337.

Mutch, R.W. 1998. Long-range fire behavior assessments: Your fire behavior future. In: Close, K.; Bartlett, R.A., eds. Fire Management Under Fire: Adapting to Change. Proceedings of the 1994 Interior West Fire Council Meeting and Program; 1997 November 1–4; Coeur d'Alene, ID. Fairfield, WA: International Association of Wildland Fire: 69–74.

Rothermel, R.C. 1972. A mathematical model for predicting fire spread in wildland fuels. Gen. Tech. Rep. INT–115. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 40 p.

Rothermel, R.C. 1983. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT–143. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 161 p.

Rothermel, R.C. 1991. Predicting behavior and size of crown fires in the Northern Rocky Mountains. Res. Pap. INT–438. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 46 p.

Rothermel, R.C. 1998. Long-range fire assessments. In: Close, K.; Bartlett, R.A., eds. Fire Management Under Fire: Adapting to Change. Proceedings of the 1994 Interior West Fire Council Meeting and Program; 1997 November 1–4; Coeur d'Alene, ID. Fairfield, WA: International Association of Wildland Fire: 169–180.

Van Wagner, C.E. 1977. Conditions for the start and spread of crown fire. Canadian Journal of Forest Research. 7: 23–24.

Van Wagner, C.E. 1993. Prediction of crown fire behavior in two stands of jack pine. Canadian Journal of Forest Research. 23: 442–449. ■