Fire Growth Modeling in the Sierra Nevada of California

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The fire growth model FARSITE (Fire ARea SImulaTor) is under development at Sequoia and Kings Canyon National Parks for purposes of simulating the spread of prescribed natural fires. This paper summarizes the state of the model as of March 1993 and the process begun to validate the technique.

The model treats fire growth as a spreading wave using equations for elliptical fire fronts developed by Richards (1989). Fire perimeters are represented by a series of points (X,Y coordinates). Calculations are made for each point to find their new positions after user-specified time-steps; collectively, these points represent the changing fire front. Under uniform conditions of topography, fuels, and weather, the fire spreads as an ellipse with eccentricity determined by the magnitude of the resultant wind-slope vector (Alexander 1985). The fire attains complex shapes, however, under actual conditions where all factors are heterogeneous.

The model requires data on topography and fuels, such as raster-based GIS (geographic information system) data themes. Weather information is currently input as files containing initial fuel moistures, daily temperature and humidity patterns, and wind changes. Temperature and humidity at an observation point were extended over the landscape as detailed by Rothermel and others (1986). Wind speed is modified for canopy coverage, but in the absence of a weather model, wind speed and direction are simply assumed to be constant during a time-step over all terrain.

To calculate fire perimeters over time, FARSITE uses fuel and topographic data from the raster nearest each point on the active fire perimeter(s). Weather and fuel moistures for that point are then computed from initial conditions using procedures developed for the BEHAVE fire behavior modeling program (Rothermel and others 1986) and the NFDRS (National Fire-Danger Rating System) (Bradshaw and others 1983). This was more computationally efficient than constructing a fuel moisture map (all cells on the landscape) at each time step. Using the wind-slope vector, forward rate of spread is calculated (Rothermel 1972) and elliptical dimensions determined (Alexander 1985). This information is used to compute the new fire front after the next time step (Richards 1989).

CAPABILITIES

The FARSITE model can run on a personal computer. The user specifies weather and GIS files and then uses a mouse to input ignition points and/or active fire perimeters on the landscape. FARSITE accepts multiple fires, which can merge (Figure 1) and form inward burning fires (burning-out an island). FARSITE displays fire perimeters color-coded by fireline intensity. The user controls temporal and spatial resolution of fire growth. Area (ha) and perimeter length (m) of the fire(s) are calculated in horizontal and topologic units. The fire, terrain, and fuels can be viewed in two or three dimensions. Output image can be saved and retrieved.

VALIDATION

Preliminary validations have been conducted using four prescribed natural fires and one wildfire occurring in Sequoia National Park. Terrain and fuels were obtained from GIS raster themes for landscapes surrounding each fire. Weather data were obtained from RAWS (remote automatic weather stations) stations near the fires or input from fire weather observations. Reduction factors were found to be necessary for obtaining realistic temporal scaling of rate of spread from the Rothermel (1972) model when applied to large spatial scales (hundreds to thousands of hectares) and temporal scales (days to weeks) of the prescribed natural fire simulations. These factors were defined by fuel type at the beginning of the simulation based on comparisons with measured spread at the head of the actual fires. Reduction factors varied from three to five for timber and grass fuel models up to 10 for some shrub fuel types and fires. Since fuel moistures in the simulations were close to measured values, these large reduction factors are interpreted as relating to the degree of spatial heterogeneity in fuels, and temporal and spatial heterogeneity in wind, all factors that are critical to fire spread but not accounted for by the Rothermel model or resolution of the data.

Similarity was assessed graphically (Figure 2) using easily obtained measures of area overlap, perimeter calculations, and rates of spread (radially from the ignition point). For each fire, actual perimeters were overlaid with modeled perimeters from comparable time-steps (Figure 3). Quantitative statistical comparisons will be made for these and for other fires from Sequoia and Kings Canyon and Yosemite National Parks.

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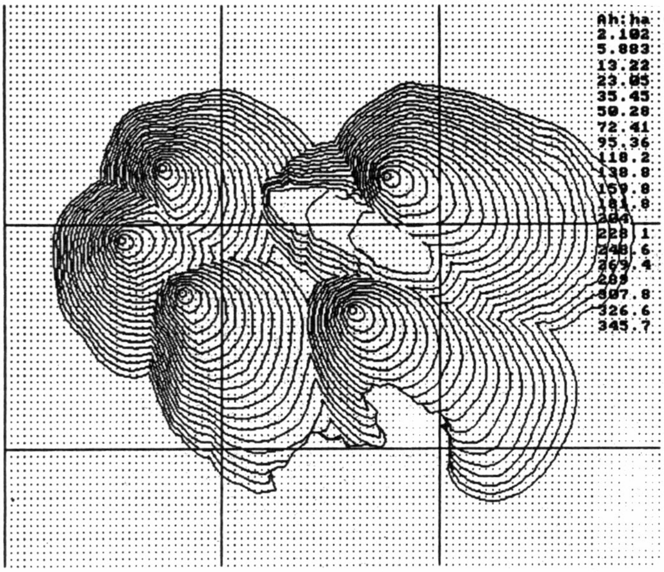

Ah:ha	As:ha	Ph:km	Ps:km
2.102	2.307	1.609	1.03
5.883	6.424	2.048	2.219
13.22	14.42	2.972	3.233
23.05	25.12	3.906	4.202
35.45	38.62	4.831	5.195
50.28	54.75	5.509	5.974
72.41	78.78	6.464	6.964
95.36	103.6	7.22	7.768
118.2	128.1	7.677	8.207
138.8	150.3	7.832	8.36
159.8	172.8	8.134	8.643
181.8	196.4	8.276	8.84
204	220.2	8.445	9.02
228 1	246.3	7.403	7.971
248.6	268.4	7.713	8.34
269.4	291.1	7.938	8.606
289	312.3	8.122	8.781
307.8	332.6	8.287	8.975
326.6	352.9	8.558	9.234
345.7	373.6	8.792	9.459

Figure 1—Example of two-dimensional output from FARSITE showing multiple ignition points and area (AH is area horizontal, AS is area surface), and perimeter (PH is perimeter horizontal and PS is perimeter surface) calculations at 4-hour time-steps. Fuels are NFFL (Nothern Forest Fire Laboratory) Model 8 except for a patch of Model 5 fuels with its higher rate of spread indicated by wide spacing between perimeters. The surface area and perimeter have been corrected for slope.

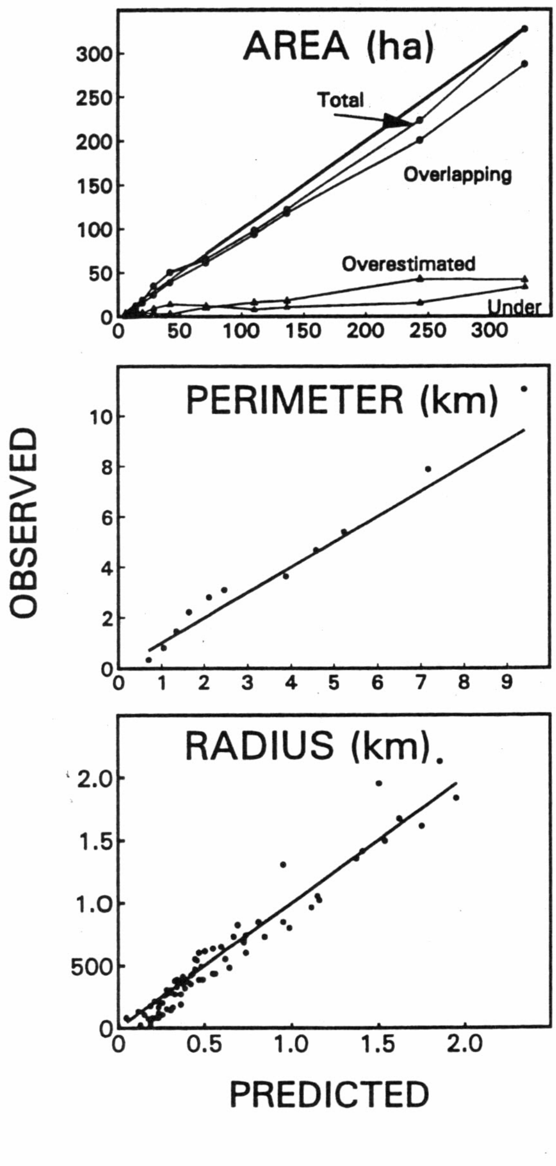

Figure 2—Comparison of predicted and actual fire spread for the Deercreek 1991 prescribed natural fire.

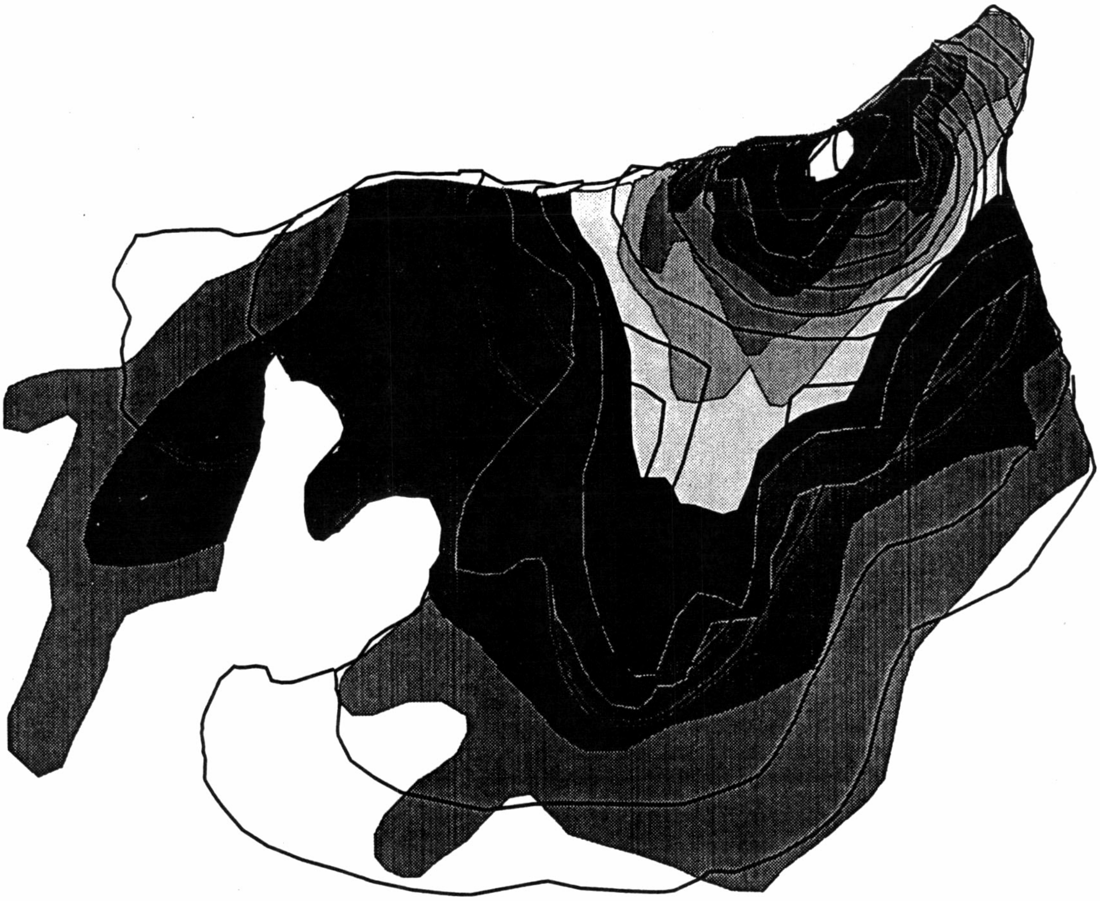

Figure 3—Overlay of perimeters for the Deercreek 1991 prescribed natural fire. Lines represent simulated perimeters; shaded areas represent actual fire spread pattern at equivalent time steps.

CONCLUSIONS

The modeling approach used in FARSITE is a very efficient technique (computationally) for simulating fire spread under complex conditions. Simulations of fire spread over several weeks took approximately 30 minutes on a PC (personal computer) with a 25 MHz 80486 processor. Initial validations suggest that the technique is valuable for projecting fire spread patterns, given that rate of spread reduction factors can be determined.

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