

# The Application of FARSITE for Assessing a Mechanical Fuel Treatment in the Eastern Sierra Nevada<sup>1</sup>

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## Abstract

FARSITE fire area simulator was used to test the effectiveness of a small mechanical fuel treatment in a bitterbrush/sagebrush shrubland in the Eastern Sierra Nevada. Custom fuel models were created for input into FARSITE using a combination of data obtained from the Southwestern Fuels Photo Series and fuels data collected at the study site for treated and untreated areas. Fuels data were calibrated to expected fire behavior by running simulations in Behave Plus 4.4b. The resultant custom fuel model map combined with other GIS data necessary for FARSITE were used to simulate fire with moderate, high, and extreme weather parameters. Results showed a decrease of fire intensity, rate of spread, flame lengths, reaction intensity, and heat per unit area as the fire transitioned from an untreated to a treated fuel bed. These methods and results are important in displaying the potential benefits of fuel treatments adjacent to wildland urban areas and building support for small area fuel treatments.

## Introduction

As the country faces another year of record acres burned in the United States, it is clear that high levels of fuels are contributing to increasing fire hazard (Skinner and Chang 1996, Graham and others 2004). Coupled with a westward demographic shift in the United States, the habitation of open space is increasing, creating a larger area of wildland urban interface. Evaluating fuel treatments in such areas is a beginning to tackling the nationwide problem of fuels and the resultant extreme fire behavior experienced during recent fire seasons.

FARSITE fire area simulator (Finney 1996) can be used to help quantify fire behavior after fuel treatments and thus is a useful tool in determining the effectiveness of these treatments. The FARSITE program simulates fires to assist land managers in predicting fire behavior. Using information on weather, wind, topography, fuels, and canopy characteristics, FARSITE displays an expanding fire perimeter at specific time intervals using a geographical information system or GIS (Finney 1996).

The limitations and assumptions of the FARSITE model are a result of the simplifications of complex fire processes necessary to decrease data requirements and excessive simulation times. The complexity of wind, weather, and fuel moisture inputs are reduced to facilitate use in the model. Hourly temporal variation for wind limits the ability to capture local wind events caused by topography (Andrews and

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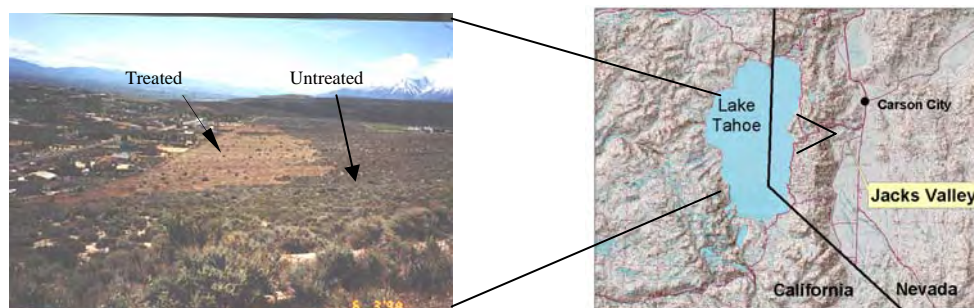
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others 2001). The resolution of raster based inputs are often determined by the 30 m digital elevation model (DEM), which assumes that conditions will remain homogenous for a minimum area of 30 m<sup>2</sup>. As a result, fine scale variability that can change fire behavior outputs may not be captured at this resolution. Despite the limitations of FARSITE, it is still used frequently in fire operations, management, and research.

This experiment introduces a method for evaluating a mechanical fuel treatment in a sagebrush/bitterbrush shrubland. The objective was to detect a difference of fire behavior outputs between mechanically treated (fuel model 41) and untreated shrub fuels (fuel model 40) using FARSITE with various combinations of wind, weather, and fuel moisture. The simulations are evaluated by FARSITE outputs such as rate of spread (ROS), flame length (FML), fire line intensity (FLI), heat per unit area (HPA), and reaction intensity (RCI). The site is located next to a housing sub-division, approximately 28 ac in size, thus exemplifying a typical wildland urban interface area (*fig. 1*).



**Figure 1**—Mechanical fuel treatment next to a housing sub-division.

## Methods

### **Simulation Area**

The study site was located south of Carson City, Nevada in Jacks Valley. Elevation ranges from 4,800 to 5,000 ft (1,460 to 1,520 m). The average annual air temperature is 50°F (10°C) while the average annual precipitation is 10 in. (25 cm) (Candland 1979). The study area is dominated by sagebrush shrublands (*Artemisia tridentata* Nutt) with antelope bitterbrush (*Purshia tridentata* (Pursh) DC) and a sparse grass understory of squirreltail (*Elymus elymoides* (Raf.) Swezey) and cheat grass (*Bromus tectorum* L.).

### **Data acquisition**

The fuels data representative of the 1:24,000 Genoa quadrangle were acquired from different sources. Initially, the fuel model map only represented the NFFL (Northern Forest Fire Laboratory) standard fuel models (Anderson 1982). These were classified as part of a fuel mapping project that encompassed 72 quadrangles in the eastern Sierra Nevada (Krauter 2001). The custom fuel models were created from fuels sampled during August of 2001 following methodology established by Brown and others (1982). This methodology was slightly altered to apply to shrubland areas. The fuels data were used to create custom fuel model 41 representing treated fuels. Fuel model 41 was composed of mainly 10 hr fuels that were masticated. Some regeneration occurred for the shrubs and herbs in this area; however, cheat grass, while present, did not compose the entire area. Due to the limitations of applying fuel

sampling methodology designed for forested areas to shrublands, a photo series was used to represent the untreated fuel model 40. Data collected from field sampling and observations were used to guide the identification of the SWSB09 (SouthWest SageBrush) fuel model in the photo series (Ottmar and others). 1 hr fuels were increased to 0.75 t ac<sup>-1</sup> to obtain acceptable spread rates and flame lengths for shrub fuels as predicted in BehavePlus (Andrews and others 2001). A series of simulations in BehavePlus were used to examine the effect of changes in 1 hr fuels, fuel depth, and surface area to volume on the outputs for the custom fuel models (*table 1*).

**Table 1**—Standard and custom fuel models for the Jacks Valley simulations. Surface area to volume (1 ft<sup>3</sup>): 1hr (2002), Live woody and herbaceous (1500).

| Custom fuel model inputs                         | Custom fuels |      |
|--|--------------|------|
| Fuel model number                                | 40           | 41   |
| 1 hour fuels (t ac <sup>-1</sup> )               | 0.75         | 0.29 |
| 10 hour fuels (t ac <sup>-1</sup> )              | 0.09         | 1.97 |
| 10 hour fuels (t ac <sup>-1</sup> )              | 0.5          | 0.38 |
| Live woody hour fuels (t ac <sup>-1</sup> )      | 2.23         | 0.23 |
| Live herbaceous hour fuels (t ac <sup>-1</sup> ) | 0.13         | 0.09 |
| Depth (ft)                                       | 2.2          | 0.8  |

Fuel moisture, wind, and weather values were obtained from the Fish Springs RAWS (Remotely Automated Weather Station) station, which was located 13.5 mi. south of the study site. Wind and weather were represented by average, 75<sup>th</sup> percentile and 95<sup>th</sup> percentile data. Fuel moisture was represented by low and average fuel moisture during the month of August for this area. Six separate simulations were done in FARSITE with different wind, weather, and fuel moisture variables to evaluate the effectiveness of the treated fuels (*table 2*).

**Table 2**—Average output from the six simulations in Jacks Valley for mechanically treated (fuel model 41) and untreated shrub fuels (fuel model 40). Outputs: FLI=fire line intensity; RCI=reaction intensity; FML=flame length; HPA=heat per unit area; ROS=rate of spread.

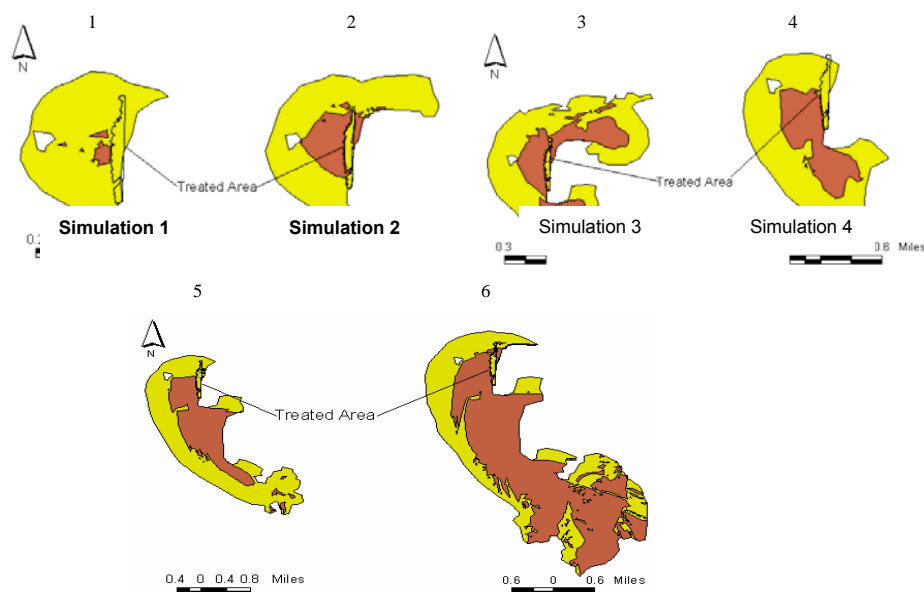
| Simulation Number | Inputs                                   | OUTPUTS     |                          |          |                          |              |
|-------------------|--|-------------|--------------------------|----------|--------------------------|--------------|
|                   |  | kW/m<br>FLI | kW/m <sup>2</sup><br>RCI | m<br>FML | kJ/m <sup>2</sup><br>HPA | m/min<br>ROS |
| 1 treated         | Weather 75 <sup>th</sup> ; average wind; | 104.5       | 4074.7                   | 0.4      | 4055.7                   | 1.3          |
| 1 untreated       | fuel moisture                            | 230.2       | 4042.3                   | 0.8      | 4629.4                   | 2.5          |
| 2 treated         | Weather 95 <sup>th</sup> ; average wind; | 198.2       | 5491.4                   | 0.7      | 5262.2                   | 1.8          |
| 2 untreated       | fuel moisture                            | 526.3       | 6058.0                   | 1.2      | 7290.5                   | 4.1          |
| 3 treated         | Weather 95 <sup>th</sup> ; average wind; | 278.4       | 6236.1                   | 0.8      | 5754.6                   | 2.4          |
| 3 untreated       | low fuel moisture                        | 707.4       | 6467.5                   | 1.4      | 8138.3                   | 5.0          |
| 4 treated         | Weather and wind 75 <sup>th</sup> ;      | 120.5       | 4542.4                   | 0.5      | 4421.3                   | 1.3          |
| 4 untreated       | average fuel moisture                    | 428.1       | 5182.2                   | 1.0      | 6197.0                   | 3.5          |
| 5 treated         | Weather and wind 95 <sup>th</sup> ;      | 213.5       | 5423.6                   | 0.7      | 5026.0                   | 2.1          |
| 5 untreated       | average fuel moisture                    | 623.1       | 5658.3                   | 1.2      | 6750.5                   | 4.9          |
| 6 treated         | Weather and wind 95 <sup>th</sup> ;      | 284.8       | 6140.9                   | 1.3      | 5470.5                   | 2.6          |
| 6 untreated       | low fuel moisture                        | 848.7       | 6652.6                   | 1.5      | 7986.1                   | 6.0          |

## Results

The treated fuels resulted in lower average values for rate of spread, reaction intensity, heat per unit area, flame length, and fire intensity when compared to the untreated fuels. This was true for both average and low fuel moisture values; 75th and 95th percentile weather; and average, 75th and 95th percentile wind inputs. Furthermore, increasing the wind and weather percentile data and decreasing fuel moisture resulted in larger values for the fire behavior outputs (*table 2*).

Rate of spread values were 56 percent more for the untreated versus treated fuels. Similarly, fire line intensity values were 64 percent more for the untreated versus treated fuels. These two outputs displayed the largest difference on average between the treated and untreated fuels. Flame length was 38 percent more for the untreated versus treated fuels.

The six fire simulations displayed in *figure 2*, showed the results of fire behavior under the different wind, weather, and fuel moisture treatments. The light colored pixels show areas where the fire line intensity did not exceed 100 Btu/ft/s and flame length was less than 4 ft. At these levels, direct attack on a wildfire is feasible at the head or flanks (Andrews and Rothermel 1982; Pyne and others 1996). The dark colored pixels show areas that exceeded 100 Btu/ft/s and flame lengths greater than 4 ft. At these levels, wildfires are managed with equipment such as plows, dozers, pumps, and retardant aircraft.



**Figure 2**—Jacks Valley FARSITE simulations 1 to 6. Dark colored areas suggest indirect tactics (flame lengths greater than 4 ft and fire line intensity greater than 100 Btu/ft/s).

Simulations 1 to 3 represented a wind direction of 270 degrees, while simulations 4 to 6 represent a wind direction of 315 degrees. This difference accounts for the change in shape of the fire perimeters after the third simulation. Simulation six represents a larger area of more severe fire behavior while the first simulation is the least severe with a small area of approximately 12.9 ac. In all the simulations, the treated fuel area (fuel model 41) displayed fire line intensities below 100 Btu/ft/s and flame lengths less than 4 ft.

## Discussion and Conclusion

The treated fuels were adjacent to a housing development on the east and were created to provide an area of defensible space against wildfire. The mechanical treatment occurred in June of 1998, allowing 3 growing seasons for the vegetation to recover from the treatment. Consequently, fuel model 41 represented a mechanically treated area 3 yr after the treatment, because these fuels were sampled and quantified in 2001.

The untreated area is a wildlife preserve. A cluster of antelope bitterbrush extends into the southern section of the treated fuels. This was done as a compromise with the homeowners in the area who suggested islands of vegetation should be included within the treated fuels for deer. However, simulations one and four are the only simulations that did not display dangerous fire behavior in this untreated section (*fig. 2*). These simulations had the least severe inputs and outputs compared to all the simulations. Patches of vegetation that exist within treated fuel breaks must be carefully evaluated and maintained. Otherwise, their existence may defeat the purpose of a fuel break as they vector fire to adjacent houses.

Generally, the treated fuels were successful at creating a buffer against dangerous fire behavior. The mechanically treated area resulted in less fuel 3 yr after the initial treatment because the vegetation was killed and had decayed. However, field sampling at this site occurred during Fall when cheatgrass (*Bromus tectorum*) was not abundant, which would result in a greater rate of spread for this treated area. Maintaining this fuel break would be one way to inhibit the increase of cheatgrass, thereby decreasing potentially higher rates of spread.

Low fuel loading for the treated area was reflected in the fuel model by decreasing the tons per acre for the 1 to 100 hr fuels, live herbaceous, and live woody fuels. The decrease of 1 hr fuels from  $0.75 \text{ t ac}^{-1}$  (untreated fuel model 40) to  $0.29 \text{ t ac}^{-1}$  (treated fuel model 41) significantly decreased the rate of spread and flame lengths. This occurred because there were not enough fine fuels to carry the fire (Burgan and Rothermel 1984). Low values for 1 hr fuels inhibit fire spread in FARSITE. Consequently, the lower fire behavior values for the treated area were not surprising.

Other factors that should be taken into consideration when explaining the results of these simulations are the limitations and assumptions of the model itself. These fuel models were created as objectively as possible; however, FARSITE intends the user to create fuel models that approximate observed fire behavior for the area at question. Realistically, fuel model 40 (untreated shrub fuel model) should have displayed flame lengths of 40 ft (Pers. comm., Forest Service fuels manager). However, even with the most extreme inputs represented in simulation 6, flame lengths did not exceed 19.9 ft. This was probably due to the low values of 1 hr fuels and high values for live woody fuels represented in fuel model 41, which act as a sink in the fire spread equation (Rothermel 1972).

The Jacks Valley treated zone was treated again in September 2001. The section of untreated fuels that extended into the treated zone was removed as well. With consistent management and policies coupled with a scientific, field-based monitoring program to evaluate the effectiveness of fuel treatments, these buffers can help to remedy the problems of urban interface, especially in the areas where houses reside with shrublands. FARSITE is a tool that can be used to display the effects of decreasing dangerous fire behavior in these fuel treatment areas, thus gaining public

support and understanding. This allows for the continued expansion of the fuel treatment programs much needed in the wildland urban interface.

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