A SIMULATION OF WILDFIRE BEHAVIOR IN PIEDMONT FORESTS

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Abstract—Decades of fire exclusion have increased the need for fuel reduction in U.S. forests. The buildup of excessive fuels has led to uncharacteristically severe fires in areas with historically short-interval, low to moderate intensity fire regimes. The National Fire and Fire Surrogate Study compares the impacts of three fuel reduction treatments on numerous response variables. At a National Fire and Fire Surrogate Study research site in the South Carolina Piedmont, fuels were altered by burning, thinning, and a combination of burning and thinning. Each treatment produced a unique fuel complex and altered microclimate for surface fuels by opening the stands to wind and light. We designed the fuel-reduction treatments to minimize damage if a wildfire were to occur, but we found fire behavior in each treatment area difficult to predict. We evaluate wildfire behavior after the fuel-reduction treatments using the BehavePlus2 fire modeling system. Custom fuel models for each treatment were developed from inventories of the litter layer, dead woody fuels, and live fuels. Microclimate variables affected by each treatment, such as crown closure, temperature, relative humidity, and wind speed, were collected over four fire seasons and used as model input. Simulation results will help determine the value of fuel reduction treatments.

INTRODUCTION

Over the past several decades fire suppression has caused excessive amounts of forest fuel accumulations throughout the United States. Increased fuel loadings can exacerbate wildfire control, cause smoke management problems, and threaten firefighter and public safety. Annually, South Carolina suppresses about 5,000 to 6,000 wildfires that burn a total of 30,000 acres.

Two studies about how fuel treatment affects on wildfire behavior in the West by van Wagtendonk (1996) and Stephens (1998) found that prescribed fire reduced severe fire behavior more than thinning. Stephens (1998) also found that thinning followed by prescribed burning would not produce extreme fire behavior at 95th-percentile weather conditions. Van Wagtendonk (1996) suggested that managing forests using a combination of fuel treatments is critical in reducing the size and intensity of wildfires. A study in Portugal by Fernandes and others (1999) found that fuel treatments consisting of any physical fuel elimination, such as prescribed burning and mechanical treatment with slash disposal, were effective short-term solutions for reducing wildfire behavior. In a similar study, Brose and Wade (2002) found that prescribed fire was the most effective treatment for immediate fuel reduction. Thinning was less effective than prescribed burning but more effective than herbicide application due to disruption of fuel continuity. Herbicide treatments resulted in no decrease in fire behavior during the first year but dramatically decreased it the second year. Brose and Wade (2002) suggested combining treatments for the most effective reduction of hazardous fuels and maintaining ecosystem health.

Fuel-reduction treatments on a South Carolina Piedmont site followed National Fire and Fire Surrogate Study (NFFS) protocols and included three replications of four treatments: control, prescribed burning, thinning, and a combination of thinning and burning. Treatments altered the fuel complex and microsite climate differently, which could produce different wildfire intensities and severities. Using measured fuel data from the treatments and extreme fire-weather as variables in our model, we estimated wildfire behavior to determine if fuel reduction treatments adequately protect forests from wildfire.

National Fire and Fire Surrogate Study

This national study compares ecological and economic impacts of fuel reduction treatments. This study consists of 13 sites across the United States where fire has played a historical role. These areas currently have excessive fuel buildup and are considered to be at risk of wildfire. Eight sites are located in the Western United States, with the remainder in the Eastern United States. Each site follows the same protocols for treatments and data collection to allow for a national database of core variables.

Location

The Piedmont NFFS study is located on the Clemson Experimental Forest in northwest South Carolina. The research sites are in second- or third-growth forest with loblolly pine *(Pinus taeda* L.*)* and shortleaf pine (*P. echinata* Mill.) as the dominant species. The fire-return interval ranges from 1 to 30 years.

METHODS

The Piedmont NFFS site consists of three replications of four treatments. Treatments used were burn only, thin only, thin and burn, and control. Within each treatment, 40 grid points were established on 50- by 50-m spacing. At each grid point, fuel data were collected on three fuel transects using the Brown's Planar Intersect Method (Brown 1974). We inventoried 1-, 10-, and 100-hour fuels and measured fuel height on each transect. We used the data to develop custom fuel models in the BehavePlus2 fire modeling system (Andrews and others 2002).

HOBO® data loggers and HOBO® micro stations were placed in a central location within each treatment area to compare treatment microsite differences. At 10-minute intervals we

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used the HOBO® data logger to record temperature and relative humidity and the HOBO® micro stations to collect wind speed data. Four additional RainWise MK3 weather stations were located in open fields on the Clemson Forest also to collect temperature, relative humidity, wind speed, and wind direction at 10-minute intervals. Weather data were downloaded monthly using a palm device or laptop computer.

We analyzed the data with the Statistical Analysis System using PROC GLM procedure (Littell and others 1996). Significance was determined at the $\alpha = 0.05$ level. We developed regression equations to predict stand weather conditions based on weather reported in open areas. Those equations estimated the high temperature, low relative humidity, and high midflame wind speed that would occur in each treatment on an 80th-percentile day during the fire season. Using estimated weather variables, BehavePlus2 simulated fire behavior in each treatment.

RESULTS

Fuel Loads

Thin-only treatments increased 1-, 10-, and 100-hour fuels, with 100-hour fuels increasing the most (fig. 1). Burn only reduced 1- and 10-hour fuels and increased 100-hour fuels. Thin and burn reduced 1-hour fuels but increased 10- and 100-hour fuels.

Weather Conditions

Ambient temperatures were lowest in the control and burn-only treatments (fig. 2). The thin-and-burn treatments had the highest ambient temperatures, which were significantly higher than the thin-only treatments. Relative humidity was lowest in the thin-and-burn treatments (fig. 3). There was no difference in the thin-only and control treatments. The burn-only treatments had significantly higher relative humidity than all other treatments. Thin-and-burn and thin-only treatments had average wind speeds around 1.75 miles per hour with no significant difference between the two (fig. 4). The control and burn-only treatments had significantly higher wind speeds, just below 2.5 miles per hour. Increased hardwood sprouting in the thin-and-burn and the thin-only treatments may be a factor in the low wind speed in these treatments.

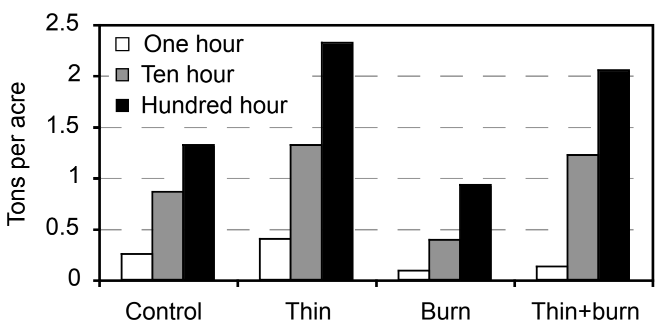

Figure 1—Average fine woody fuels in tons per acre on all treatments posttreatment.

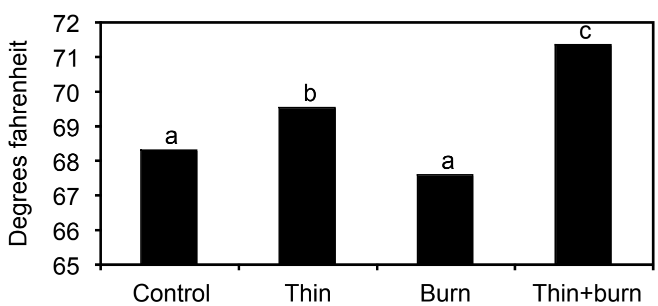

Figure 2—Maximum ambient temperature in degrees Fahrenheit posttreatment.

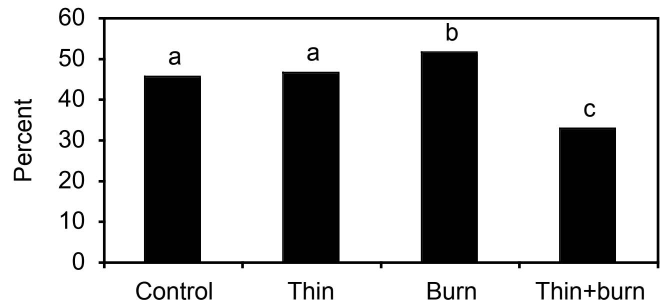

Figure 3—Lowest percent relative humidity posttreatment.

Wildfire Behavior

BehavePlus2 (Andrews and others 2002) predicted that wildfire flame lengths would be tallest in thin-and-burn and thin-only treatments where 10- and 100-hour fuel loads were high (fig. 5). Rate of spread was fastest in the control and burn-only treatments (fig. 6). The rate of spread module is influenced by wind speed, and the highest wind speeds were in the control and burn-only plots. Scorch height was lowest in burn-only areas due to reduced fuels (fig. 7).

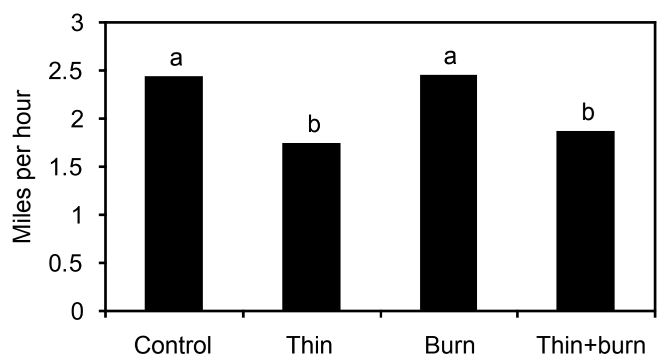

Figure 4—Maximum wind speed in miles per hour posttreatment.

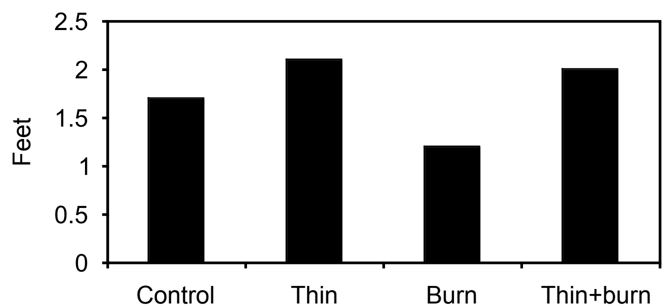

Figure 5—Maximum simulated flame length posttreatment in feet by BehavePlus2.

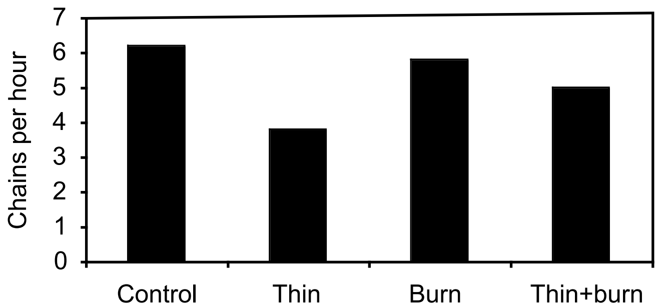

Figure 6—Maximum simulated rate of spread posttreatment in chains per hour by BehavePlus2.

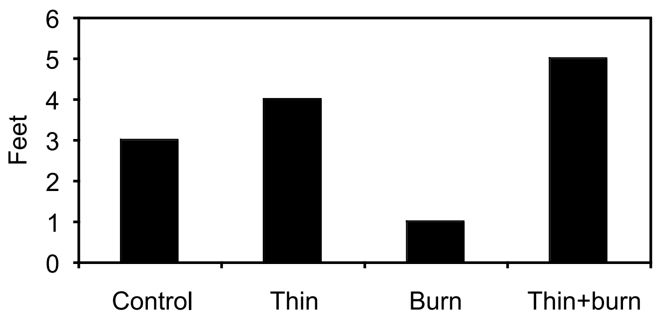

Figure 7—Maximum simulated scorch height in feet posttreatment by BehavePlus2.

DISCUSSION

The BehavePlus2 models show marginal differences in wildfire behavior among treatments, but this may change as fuels settle and decompose, vegetation continues to grow, and additional prescribed burning occurs. With the information provided here, managers can concentrate on ecological and economic results from the NFFS study when choosing management alternatives. Concerns for preventing severe wildfire will become secondary to maintaining or restoring ecosystem function. The marginal differences will allow managers to choose among treatments and achieve similar control of wildfire. Such flexibility will allow greater freedom to meet specific management objectives.

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