FUELS, FIRE SEVERITY, AND INVASIVE PLANTS WITHIN THE CERRO GRANDE FIRE, LOS ALAMOS, NEW MEXICO

Philip N. Omi, Erik J. Martinson, Mohammed A. Kalkhan, Geneva W. Chong, Molly Hunter, and Thomas J. Stohlgren

Western Forest Fire Research Center, Colorado State University, 131 Forestry, Fort Collins, CO 80523

ABSTRACT

The severity of the 2000 fire season has increased public awareness of a widespread fuels problem in western U.S. forests. Federal land management agencies have responded with plans to greatly expand programs to mitigate hazardous fuel conditions. However, scant information exists on the efficacy of fuel treatments for mitigating wildfire severity. There is even less information regarding the influence of fuel treatments on second-order fire effects, such as invasive plants. A unique opportunity to address this research void has been provided by the 2000 Cerro Grande Fire near Los Alamos, New Mexico.

The Cerro Grande Fire burned over multiple dispersed stands that had previously been treated with a variety of methods, which included thinning with and without slash removal. Immediate post-fire sampling focused on fire severity comparisons in adjacent treated and untreated stands. Ratings of crown damage and ground char were lower in treated stands than in adjacent untreated stands (paired *t*-test, $P < 0.05$). We attribute these differences primarily to lower tree density in treated stands ($P < 0.05$). Reductions in fire severity were somewhat greater in thinned stands where slash was left than in thinned stands where slash was removed, though differences between these treatment types were not significant. This mixed result may be due to chance but could imply that, under extreme fire conditions, stand density may be a more important determinant of fire behavior and effects than surface fuel load.

We greatly expanded our sampling effort in the summer of 2001 with a stratified random sampling design and multiscale plots to assess relationships among fuel treatments, stand conditions, fire severity, and invasive plants. Strata included aspect, elevation, cover type, fuel treatment type, and fire severity. Preliminary results indicate that percent relative invasive cover is higher in ponderosa pine (*Pinus ponderosa*) stands compared with other vegetation types sampled, though lower in fuel-treated areas. Relative invasive cover was also highest in severely burned areas and lowest in unburned stands. Further, the invasive plant species threat is lowest in stands that were both thinned and burned. Continuing analyses should improve our understanding of the potential ecological consequences of expanded fuel treatment activities.

keywords: Cerro Grande Fire, fire severity, fuel treatments, invasive plants, New Mexico, *Pinus ponderosa*, ponderosa pine, multiscale sampling.

Citation: Omi, P.N., E.J. Martinson, M.A. Kalkhan, G.W. Chong, M. Hunter, and T.J. Stohlgren. 2004. Fuels, fire severity, and invasive plants within the Cerro Grande Fire, Los Alamos, New Mexico. Pages 141–148 *in* R.T. Engstrom, K.E.M. Galley, and W.J. de Groot (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Forest managers have long-debated the efficacy and use of fuel treatments to reduce fire hazard in an area. The U.S. National Fire Plan (http://www.fireplan.gov/), developed following the 2000 fire season, changed this dialog by ratifying principles provided in the national cohesive strategy (USDA Forest Service 2000), which identified 16,000,000 ha of U.S. wildlands in need of urgent treatment. These areas consist primarily of long-needled pines in the western and southeastern U.S., many of which are assumed to have missed one or more fire events during the previous century of fire exclusion (Swetnam et al. 1999).

Even so, evidence of actual hazard reduction has generally lagged behind advocacy claims for fuel treatment due to a variety of reasons. Only a handful of studies attempt to quantify the effects of fuel treatment on subsequent wildfire severity or effects (e.g., Omi and Kalabokidis 1991, Weatherspoon and Skinner 1995, Pollet and Omi 2002). This lack of scientific inquiry is puzzling, but possible reasons may include lack of interest on the part of researchers, managers, and lay publics (i.e., inherent beliefs in the success or failure of earlier fuel treatment efforts), unavailability of funding, or perhaps, insufficient documentation of wildfire encounters with previously treated areas. Despite anecdotal evidence suggesting that fuel modification reduces the intensity of eventual wildfires, skepticism remains—possibly because of

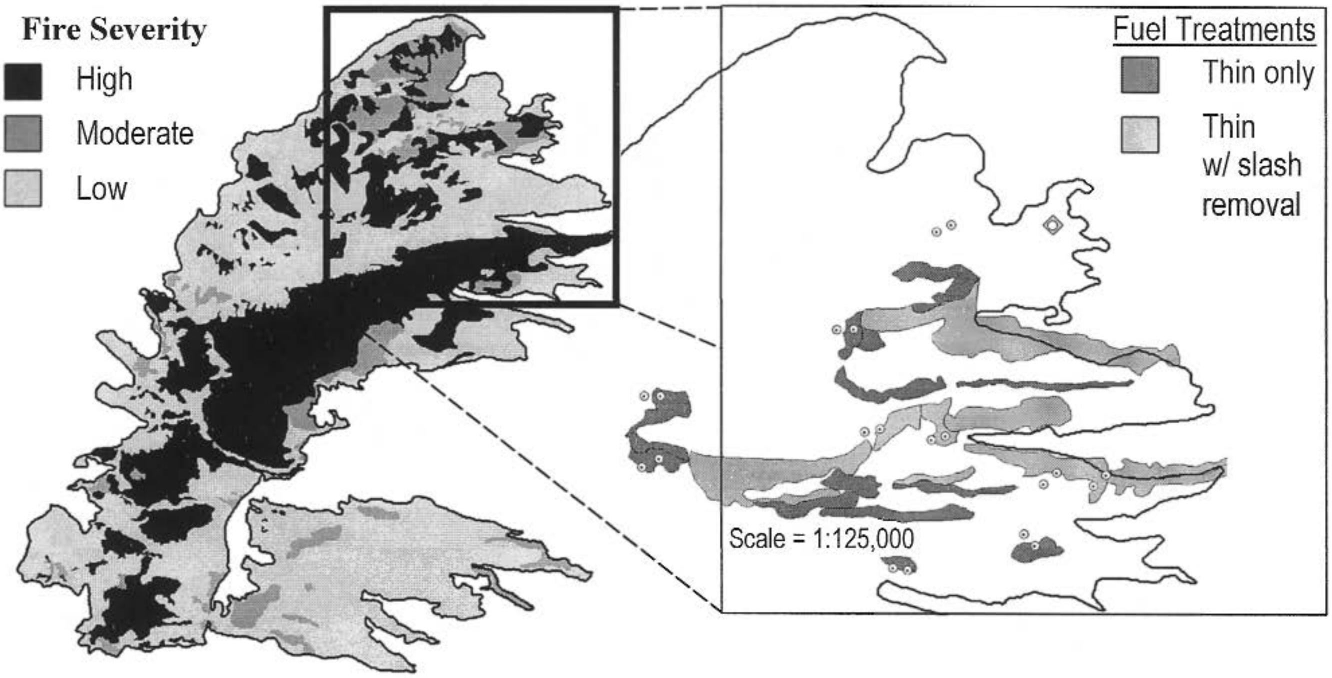

Figure 1. Location of fuel treatment areas for the initial study of fire severity within the Cerro Grande Fire perimeter, Los Alamos, New Mexico. Burn severity downloaded from Burn Area Emergency Rehabilitation website. Fuel treatment type and locations provided by the Santa Fe National Forest.

theoretical expectations that might associate forest openings with higher ignition probabilities and rates of spread, i.e., due to increased solar radiation, higher wind speeds, and favorable understory fuel conditions (Agee et al. 2000).

This paper describes the evolution of a multiphase project aimed at establishing the performance attributes of fuel treatment sites exposed to eventual wildfires. We focus on an ongoing, multidisciplinary investigation of fire and fuel treatments within the 2000 Cerro Grande Fire, near Los Alamos, New Mexico. The Cerro Grande Fire is the seventh in a series of eight fires that we have investigated to various degrees since 1995 (Omi and Martinson 2002, Pollet and Omi 2002). Collectively these sites provide us with the most extensive database ever compiled for fuel treatment effects on wildfire severity. The effects of fuel treatments on subsequent wildfire severity has been at the core of each fire examined; however, as noted herein, we have branched into a much broader inquiry including possible repercussions in terms of the spread of invasive plants.

STUDY AREA

The Cerro Grande Fire started as a prescribed burn in Bandelier National Monument on 4 May 2000. On 7 May, the fire escaped control lines and eventually spread north, south, and east, entering the town of Los Alamos on 10 May and destroying 405 residences (Larese 2001). During its 10-week life (control was not declared officially until 20 July) the fire affected nearly 19,300 ha, including lands managed by the Los Alamos National Laboratory, USDA Forest Service (Santa Fe National Forest), San Ildefonso Pueblo, Santa Clara Pueblo, as well as private and municipal lands.

As in any landscape-scale burn, the Cerro Grande Fire exhibited considerable variability in the fire's spread pattern, including areas that burned with high, low, and mixed severity in response to fuel, weather, and topographic gradients. Our primary objectives were to isolate the effect of fuels modification on fire severity and assess the influence of fire severity on invasive plants.

METHODS

Year 2000 Assessment of Fuel Treatment Effectiveness

The Cerro Grande Fire met criteria established previously (i.e., see Pollet and Omi 2002) of fuel treatment effects on wildfire severity: 1) Recent wildfire burned adjacent and topographically similar treated (within the last 10 years) and untreated areas (i.e., >20

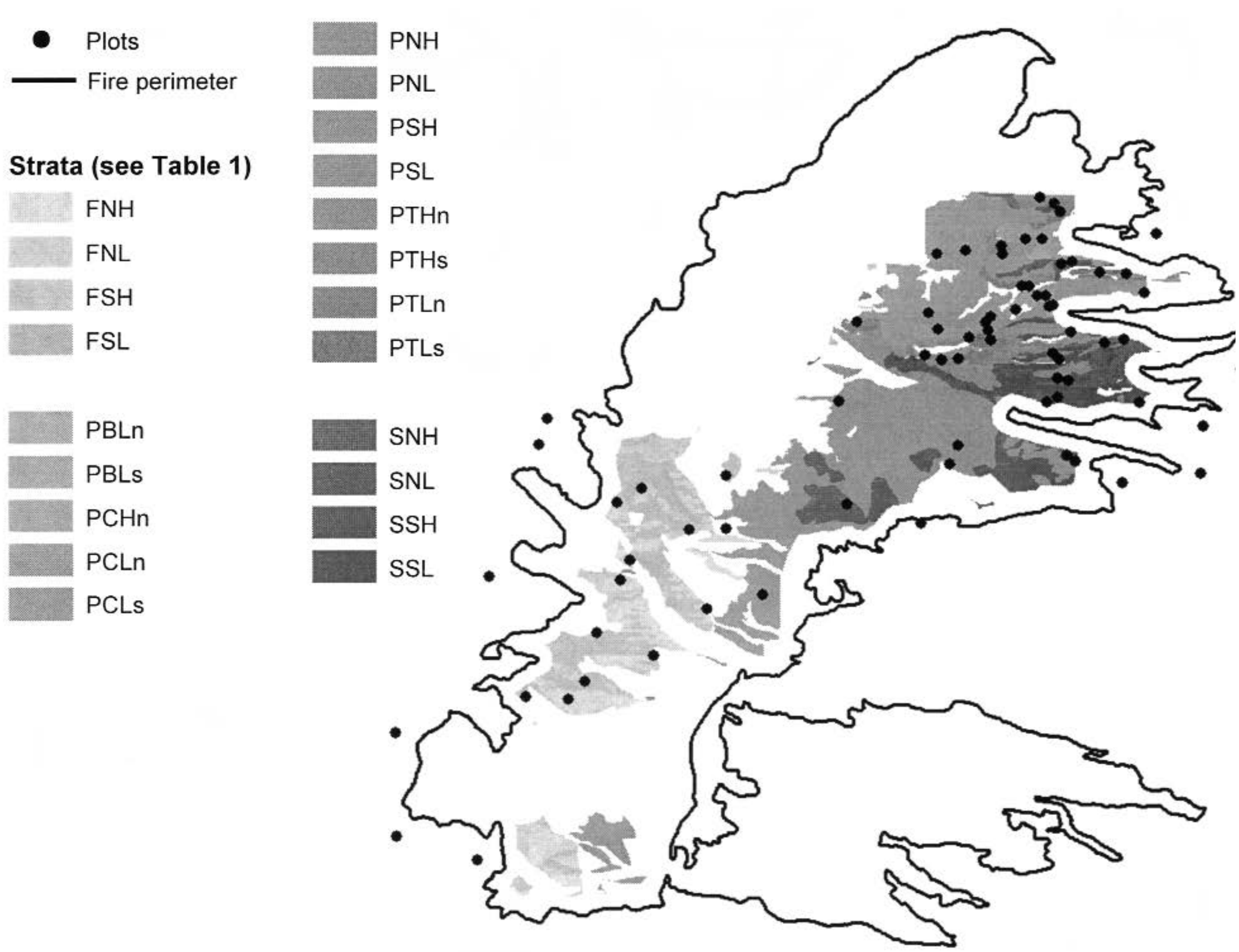

Figure 2. Modified-Whittaker plot locations for the expanded study of fuel treatments, wildfire severity, and invasive plants within strata of the Cerro Grande Fire, Los Alamos New Mexico. Strata codes are defined in Table 1.

years without manipulation); 2) Detailed information was available on treatment types, dates, and boundaries within the fire perimeter; and 3) No suppression activity occurred near study sites.

Establishing these guideline criteria maximized the likelihood that differences between burned areas were due to treatment and not to other phenomena, such as changes in weather or topography, natural barriers, or roads. Also, we focused on areas where the pre-wildfire treatment objectives were fuel hazard reduction rather than other management objectives (such as wood production). Further, we relied on manager-provided definitions for the types and levels of fuel treatment. No information was available on pre-wildfire fuel conditions (e.g., loading), although each treatment–control pair was selected to be as similar as possible with the exception of the fuel manipulation.

Armed with available information on historic treatments, maps, fire spread characteristics, and pre-fire vegetation types, we stratified the burn area for field sampling. The sampling protocol called for aligning treatment–control pairs in the general direction of fire spread, with treated areas to the lee side of untreated areas so that the fire spread through untreated fuels before encountering the treatment area. The Cerro Grande Fire burned primarily in ponderosa pine, pinyon–juniper (*Pinus edulis–Juniperus monosperma)*, and mixed forest communities, spreading into areas where smaller-diameter trees had been thinned mechanically (hand crews with chain saws), with and without slash removal. Slash removal methods usually involved controlled burning, though in one stand (on Santa Clara Pueblo land) the slash had been physically removed (Figure 1).

The arrangement of fuel treatments in the Cerro Grande Fire was unique in that it allowed a kind of replication rarely afforded by wildfires that involve fuel treatments. Paired treated and untreated plots were separated by 250 m, equidistant from the treatment boundary on similar slope and aspect. The prox-

Table 1. Cerro Grande Fire landscape stratification to randomly locate multiscale plots for inventory of invasive plants, Los Alamos, New Mexico.

Aspect	Elevation (m)	Vegetation	Treatment	Severity	Replications	Code
S	2100–2500	Pinyon–juniper	None	Low	3	SSL
S	2100–2500	Pinyon–juniper	None	High	3	SSH
N	2100–2500	Pinyon–juniper	None	Low	3	SNL
N	2100–2500	Pinyon–juniper	None	High	3	SNH
N	2100–2500	Ponderosa pine	Thin	Low	3	PTLn
N	2100–2500	Ponderosa pine	Thin	High	3	PTHn
S	2100–2500	Ponderosa pine	Thin	Low	3	PTLs
S	2100–2500	Ponderosa pine	Thin	High	3	PTHs
N	2100–2500	Ponderosa pine	Thin–burn	Low	3	PCLn
S	2100–2500	Ponderosa pine	Thin–burn	Low	3	PCLs
N	2100–2500	Ponderosa pine	Burn	Low	3	PBLn
S	2100–2500	Ponderosa pine	Burn	Low	3	PBLs
S	2100–2500	Ponderosa pine	None	Low	3	PSL
S	2100–2500	Ponderosa pine	None	High	3	PSH
N	2100–2500	Ponderosa pine	None	Low	3	PNL
N	2100–2500	Ponderosa pine	None	High	3	PNH
S	2500–3000	Mixed forest	None	Low	3	FSL
S	2500–3000	Mixed forest	None	High	3	FSH
N	2500–3000	Mixed forest	None	Low	3	FNL
N	2500–3000	Mixed forest	None	High	3	FNH
S	2100–2500	Low elevation	None	Unburned	3	LSU
N	2100–2500	Low elevation	None	Unburned	3	LNU
S	2500–3000	High elevation	None	Unburned	3	HSU
N	2500–3000	High elevation	None	Unburned	3	HNU

imity and topographic similarity of the paired plots allowed us to attribute any fire-related differences to fuels modified by treatment.

Our sampling design employed point sampling (Avery and Burkhart 1983) of variable radius plots in which we reconstructed pre-fire stand conditions (crown position, crown base height, tree height, diameter at breast height, tree density) and evaluated fire severity indicators (scorch height, crown volume scorched–consumed, stand damage rating, and ground char rating) following procedures outlined by Ryan and Noste (1985) and Omi and Kalabokidis (1991). These criteria provide a consumption-based metric of the ecological effects of a fire (above- and belowground) as it spreads over a landscape.

Year 2001 Invasive Plant Survey

We followed up our initial findings regarding fuel treatment effects on fire severity with a more intensive, multiscale examination (remote sensing, aerial photography, field inventory) of the interactions among wildfires, fuel treatments, and invasive plants, using procedures outlined in Kalkhan et al. (*this volume*). We sampled a much larger area within the Cerro Grande Fire (Figure 2), with the intent of developing GIS-based predictive tools for estimating the propensity of invasive plants to occupy burned sites, with and without treatment.

We stratified the Cerro Grande burn landscape with spatial information on the basis of aspect, elevation, fire progression, fire severity, pre-fire vegetation type, and presence–absence of fuel treatment (Table 1). For this expanded study of invasive plants, treatments included areas that were thinned, thinned–burned, and prescribed burned only. Our sampling design included at least three modified-Whittaker plots (after Stohlgren et al. 1995) established in each of 20 strata in burned areas and 4 strata in unburned areas. In each plot we measured understory and overstory vegetation, fire severity, and soil variates.

We analyzed data collected in 2001 for invasive plant trends within various strata established prior to field sampling. These included 1) relative invasive plant cover in different vegetation types (compared with unburned areas); 2) relative invasive plant cover in areas of differential burn severity (high, low, and unburned); and 3) relative invasive plant cover by different treatment strata (thin, prescribed fire, thin and prescribed fire, and untreated).

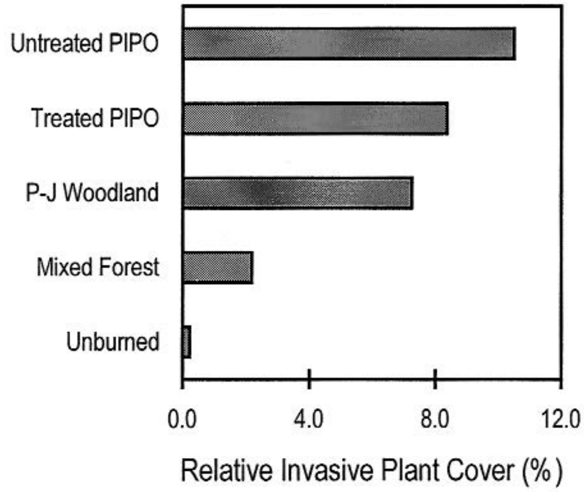

Figure 3. Mean percent relative invasive cover found in different vegetation types and unburned areas for the expanded study of invasive plants within the Cerro Grande Fire, Los Alamos, New Mexico, including untreated and treated ponderosa pine (PIPO) stands and pinyon–juniper (P-J) woodlands.

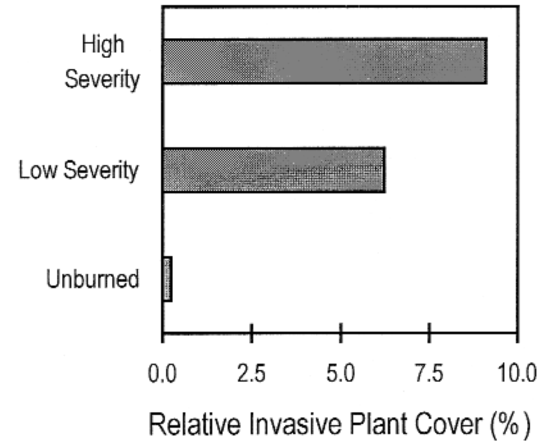

Figure 4. Mean percent relative invasive cover found in the expanded study of invasive plants in high-severity fire, low-severity fire, and unburned areas within the Cerro Grande Fire, Los Alamos, New Mexico.

RESULTS

Year 2000 Assessment of Fuel Treatment Effectiveness

The central hypothesis of our assessment of treatment effects was that fuels modified by treatment reduce wildfire intensity, as evidenced by post-fire severity indicators. Treated areas within the Cerro Grande burn had lower tree densities (number per hectare) than adjacent untreated areas ($P < 0.05$; Table 2). This difference was most apparent in areas that had been thinned followed by slash burned. Stands that had been thinned and burned also exhibited higher crown base heights ($P < 0.10$; Table 2).

Crown damage ratings were significantly lower in Cerro Grande stands where fuels had been treated, both with and without slash removal ($P < 0.05$; Table 2). Average ground char ratings were lower in treated areas, though only significantly so when treatments are combined ($P < 0.05$; Table 2)—possibly an artifact of small sample sizes (i.e., five treated–untreated pairs for each treatment type).

Year 2001 Invasive Plant Survey

Preliminary results suggest that percent relative invasive cover varied by vegetation, treatment, and burn severity strata. Mean percent relative invasive cover was highest in burned ponderosa pine stands, though burned areas that had been treated appeared to have less invasive cover (Figure 3). Invasive cover also was influenced by burn severity (Figure 4), with highest relative cover in the most severely burned areas. Invasive plants were least prevalent on unburned sites. Thus, our preliminary findings support the idea that fuel treatment effects on invasive plants must be assessed within vegetation and fire-severity strata.

Fuel treatments in the Cerro Grande Fire were restricted to ponderosa pine sites and all treated areas that were thinned with slash removal burned with low severity. Among these ponderosa pine stands that burned with low severity, we noted higher invasive

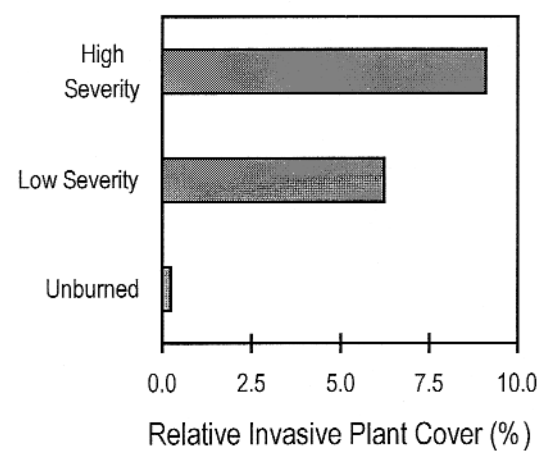

Figure 5. Average percent relative invasive cover found in the expanded study of invasive plants in ponderosa pine stands of the Cerro Grande Fire, Los Alamos, New Mexico, including treated areas (thinned only, thinned and burned, and prescribed burned only) versus untreated areas. All treated areas burned with low severity in the wildfire.

Table 2. Tree characteristics (density and crown base height) and fire severity ratings (crown damage and char depth ratings) for paired treated and untreated stands (n = 5 pairs in each of two treatment types) in the Cerro Grande Fire, Los Alamos, New Mexico. Treatments included thinning with slash removal (by burning or physical removal) and thinning only. For comparison purposes, results are presented with and without separation by treatment type.

Treatment comparison	Tree density (no./ha)	Crown base height (m)	Crown damage rating (0–4)	Char depth rating (0–4)
Thin–slash removal				
Treated	176.0**	4.3*	1.8**	0.9
Paired, untreated stands	576.0	2.3	2.8	1.3
Thin only				
Treated	420.0	3.0	2.4**	1.2
Paired, untreated stands	640.3	4.2	3.4	1.7
Total				
Treated	298.0**	3.6	2.1**	1.0**
Untreated	608.1	3.2	3.1	1.5

* $P < 0.10$.
** $P < 0.05$.

cover on thinned-only sites than in untreated areas (Figure 5). However, stands that were both thinned and burned had the lowest relative invasive cover (Figure 5).

DISCUSSION

Our year 2000 sampling efforts confirmed that fuel treatments can reduce wildfire severity, largely through reductions in tree density. Overall ratings of crown damage and ground char were lower in treated stands than in adjacent untreated stands. We attribute these differences primarily to lower tree density in treated stands. Reductions in ground char depth were somewhat greater (though not significantly) in thinned stands where slash was left than in thinned stands where slash was removed, while crown damage ratings were reduced equally by the two treatments. These results imply that under extreme winds, such as those that propelled the Cerro Grande Fire, stand density may be a more important determinant of fire behavior and effects than surface fuel load. Additional research linking observed fire behavior (under extreme wind conditions, e.g., in excess of 40–50 km/h) with quantified pre-fire fuel loads and stand densities would be needed to confirm this possible relationship.

Our studies in long-needled pine systems of the western and southeastern U.S. (Omi and Martinson 2002, Pollet and Omi 2002) indicate that fuel treatments often reduce wildfire severity. This is not to say that mechanical thinning and/or prescribed burning will always reduce wildfire severity. In fact, under the right burning conditions an active or independent crown fire may spread through fuel treatment areas, depending upon type of treatment–slash disposal, time elapsed since treatment, pre-wildfire fuel profiles, and weather conditions. Treatment may increase surface fire intensity by increasing solar radiation and the abundance of flashy fuels, as well as by wind barrier reduction. Further, thinned areas with or without slash removal may both burn severely under extreme weather conditions. However, by reducing the continuity of aerial fuels, treatments often mitigate crown fire potential and extreme stand damage. Given the complexity of interactions that influence extreme fire behavior, we are impressed with the uniformity of evidence from eight different wildfires suggesting reductions in wildfire severity due to fuel treatments. Future synthesis of these data may indicate treatment intensities that generally reduce wildfire severity to acceptable levels in long-needled pine systems.

Future studies would shed additional insight if greater attention could be directed toward defining fuel treatments, specifically the methods of thinning and slash removal. In our fire severity study, we relied on manager-provided definitions of areas that had been thinned mechanically from below (i.e., smaller-diameter trees) by hand crews with chain saws, with and without slash removal (by burning and physical removal). Our subsequent study of invasive plants included mechanically thin, thin–burn, and prescribed burn treatment areas. Clearly stand density, residual tree diameters, and subsequent fire behavior could be affected by differential thinning standards (e.g., below, crown, or selection). Slash disposal techniques (e.g., pile-burning, or physical removal by hand-crews and/or mechanized equipment, such as tractor, feller-buncher, or helicopter) must also be considered.

Time did not permit a more rigorous examination of all the data collected during the summer of 2001. Our preliminary results from 2001 indicate some potentially interesting trends, although additional detailed data analyses will be required for substantiation. Other questions that we intend to explore in our continuing analyses and in future burns include 1) To what extent is fire severity related to stand conditions? 2) Does fire severity affect the likelihood and persistence of invasive plants? 3) Do disturbances created by pre-fire treatments provide a source for post-fire increases in invasive plant species? 4) To what extent does risk of post-fire invasive plants vary with aspect, elevation, and cover type? 5) Do invaded areas represent a greater post-fire fuel hazard?

Finally, invasive species identified in our study included those used in burned area rehabilitation efforts, e.g., common barley (*Hordeum vulgare*) and Italian ryegrass (*Lolium multiflorum*). Their prevalence and geographic distribution in our study area raise questions about the general efficacy of rehabilitation treatments that we hope to pursue in the future.

MANAGEMENT IMPLICATIONS

Fuel treatments reduce wildfire severity most of the time, but perhaps their greatest contribution lies in the options they provide for managing a landscape. These options include safe access–egress for firefighters, as well as possible counter-firing opportunities (Omi 1996). However, relatively few fires encounter fuel treatment areas. In the Cerro Grande Fire relatively few areas were treated within the burn perimeter. This suggests the enormity of the task at hand if fuels are ever to be treated at a sufficient scale to make a marked impact on wildfires burning over western landscapes.

A major concern impeding the expansion of fuel treatment activities is fear of promoting invasive plants. However, preliminary results from our Cerro Grande analysis suggest that relative invasive plant cover was relatively higher in unthinned ponderosa pine stands and in the most severely burned areas. Further, among ponderosa pine sites that burned with low severity, invasive plant cover was lowest in areas that had been thinned and burned. If these preliminary results are confirmed through further statistical testing and in our intended future sampling of burned areas, then managers may need to consider the possible use of fuel treatments to mitigate the spread of invasive plants.

ACKNOWLEDGMENTS

We thank the Joint Fire Science Program and McIntire-Stennis Forestry Research Program for funding this research. Steve Desipio, Li-Ming Liang, Ben Chemel, Rod Rochambeau, Mike Alexander, German Flores, and Nikki Omi provided field assistance. Rick Shory and Sara Simonson provided botanical support, and Esther Schnur contributed data entry assistance. We also acknowledge agency cooperation from the Santa Fe National Forest, Bandelier National Monument, Los Alamos National Laboratory, U.S. Geological Survey, Bureau of Indian Affairs, and Santa Clara Pueblo. Finally, we appreciate the helpful comments provided by manuscript reviewers.

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