

Reduction of Fire Hazard through Thinning/Residue Disposal in the Urban Interface

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Abstract. Alternative fire hazard reduction techniques are needed for managing fuel profiles in forest ecosystems located within the so-called wildland-urban interface. The present study includes experimental fuel manipulations initiated along the Rocky Mountain National Park interface with residential areas in Colorado, USA. Three thinning/slash disposal treatments were applied on two lodgepole pine (*Pinus contorta*) stands: thinning with whole-tree removal; thinning with stem removal — lopping and scattering; and thinning with stem removal — hand piling and burning. Results indicate that treatments reduced surface fire behavior parameters, bringing them down and closer to limits of direct attack methods. Crown fire potential was decreased not only because of canopy removal, but also as a result of potential reduction in heat generated by surface fuels. Projected fire behavior for the thinning-without-slash-removal scenario indicates the possibility of serious control problems with major fire runs and crown fires given an outbreak.

Keywords: Forest fires; Fuels management; Wildland-urban interface; Colorado; *Pinus contorta*.

Introduction

Fuel management becomes increasingly critical in forest ecosystems located adjacent to residential areas (the so-called wildland-urban interface) because of adverse physical forces, increased fire risks, and unique resource values. Fire managers often seek many alternative treatments for modifying wildland fuel profiles within the urban interface. From an ecosystem management perspective, understory broadcast burning may be desirable; however, sociopolitical constraints often preclude its implementation. A similar dilemma confronts fire and fuel managers in national parks characterized by important natural resource values and uses. This dilemma is compounded in other regions, such as high elevation parks, where climatic regimes and/or anomalies limit the opportunities for prescribed burning. High

fuel loadings, after decades of fire exclusion, exacerbate the problem.

Warm and dry summers desiccate wildland biomass, adding to fuel stockpiles which accumulate over time due to epidemics and other sources of tree mortality. Hazardous fuel situations — created by human and natural disturbances — can be proactively managed before wildfires occur. Land and fuel management practices are known to dramatically affect fire behavior potential through fuel buildup and treatment. However, one issue confronting land managers relates to the effectiveness of these practices as a means of reducing fire hazards. This concern informed the focus in the present study and provided rationale for its objective: i.e., to determine differences in fuel bed characteristics and fire behavior of three fuel management practices in the wildland-urban interface.

This issue is important in ecosystems of the western United States where large fire outbreaks can occur due to the prolonged drought, hazardous fuels, and annual lightning fire season. Fuels management (with prescribed fire or other cultural, mechanical, biological, and chemical methods) is being applied, but knowledge of its impact on hazard reduction is ecosystem-specific and limited. For example, fuelbreaks and other fuel modifications for wildland fire control have been addressed in Mediterranean-type ecosystems (Green 1977). A harvesting study in mature lodgepole pine (*Pinus contorta*) compared four harvesting and logging residue treatments, with results predicting considerably lesser fire behavior potential on the residue-removed treatments (Benson 1982). Wakimoto et al. (1988) showed the relative effectiveness of alternative slash disposal treatments aimed at reducing fire hazards in ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii*) forests; six treatments — involving piling, burning, and wood removal — were tested and displayed significantly reduced fire potential.

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The present study was conducted on two high elevation forested sites at Rocky Mountain National Park (RMNP) in Colorado, USA. The first site was located along the southeast boundary of the Park adjacent to the town of Allenspark; the area contained a densely stocked lodgepole pine stand at 2650 m elevation, and showed an average of 30% slope with predominantly north-easterly through easterly aspects. The second study site was located along the western Park boundary, adjacent to Columbine Lake residential area in the town of Grand Lake; the terrain was gently rolling at 2620 m elevation and was covered with a moderately dense lodgepole pine stand. Each study site was divided into three 0.4 ha blocks and the following thinning/slash fuel treatments were applied in each block, respectively:

- Treatment 1. Thinning with whole-tree removal.
 Treatment 2. Thinning with stem removal — lopping and scattering.
 Treatment 3. Thinning with stem removal — hand piling and burning.

On the average, thinning reduced tree density from 400 to 300 trees/ha. Trees were felled by chain saws and saw logs were bucked out to a 7.5-cm minimum diameter (small end). Bucking was done directly after felling, and all felled stems (including tops from Treatment 1) were hand-carried and piled outside the units boundaries for use as firewood. In Treatment 2, branches of tree tops were lopped and scattered so the material would lie closer to the ground to reduce fuel depth and expedite decay. Slash piles were hand-constructed in

Treatment 3 not only to reduce fire hazard, but also to improve accessibility and appearance of the site; the green slash piles were allowed to desiccate for a year before burning.

The inventory of downed fuels was based on the planar intersect technique of Brown (1974) for woody material, and load-depth relationships used in BEHAVE (Burgan and Rothermel 1984) for litter fuel. Eight sample points were established along the two diagonals of each study block. Each sample point was marked with metal stakes and numbered metal tags. Thus, fuels were inventoried prior to and after the treatments and site-specific fuel models were constructed with the BEHAVE fire behavior and fuel modeling system.

In addition, the average amount of slash that would have been produced by thinning with no slash treatment was predicted using the timber stand inventory, slash weight tables developed by Brown et al. (1977), and BEHAVE's NEWMDL computer program (Burgan and Rothermel 1984). Total weight of small diameter fuel (woody plus litter) was calculated in both study sites from the average number of trees cut per hectare by their average diameter at breast height, as described by Brown et al. (1977). Potential crown fire behavior was assessed utilizing crown fire nomograms (Rothermel 1991), in conjunction with Brown's et al. (1977) crown fuel tables (employed as previously) and combined fuel data from all three treatments.

Fire behavior potential of each fuel treatment (and the "no slash treatment" hypothetical scenario) was simulated for the following environmental conditions, representing "average-worst" local situations:

Table 1. Pre- and post-treatment fuel inventory in Rocky Mountain National Park for each treatment (thinning with whole-tree removal; thinning with stem removal — lopping & scattering; and thinning with stem removal — handpiling & burning). Within a row, means followed by the same letter are not different at the 10% significance level.

FUEL COMPONENT (unit)	TREATMENT					
	Tree Removal		Lop & Scatter		Pile & Burn	
	PRE	POST	PRE	POST	PRE	POST
SMALL WOODY ¹ (t/ha)	10.7a	8.5b	7.4c	7.1c	8.0d	3.1e
LARGE WOODY ² (t/ha)	11.8a	7.6a	7.3b	4.3c	6.2d	8.7d
LITTER ³ (t/ha)	12.0a	9.8b	9.0c	7.6d	10.5e	6.3f
DEPTH ⁴ (cm)	11.5a	7.5b	7.1c	5.8d	11.7e	3.6f

¹Total downed fuel < 7.5 cm in diameter.

²Total downed fuel > 7.5 cm in diameter.

³Litter layer consisted of needles, bark, and cone parts.

⁴Total woody and litter fuel depth.

1-h timelag fuel moisture:	3 percent
10-h timelag fuel moisture:	4 percent
100-h timelag fuel moisture:	5 percent
Midflame windspeed:	15 km/h
Slope:	30 percent

Results

Table 1 shows a comparison of the treatments with respect to forest fuels in the study area. The total downed dead loading ranged approximately from 25 to 35 t/ha prior to treatment, and 20 to 25 t/ha following treatment. Note that almost 38% of this fuel loading is made of litter, not woody, material prior to and after treatment. Grasses and shrubs were sparse and were not included in the inventoried fuel profile. The total before- and after-treatment fuel depth for the study area varied between 3.6 cm and 11.7 cm.

The variability in these fuel inventory estimates (Table 1) may result from several sources, including differences due to site and sampling procedures. Though located at comparable elevations and vegetation cover types, the Allenspark and Grand Lake sites are on opposite sides of the continental divide. Site selection was confined by the locations where treatments were planned by National Park Service personnel. Although considerable variability existed between and within sites we feel confident that treatments were replicated in both areas and thus analyzed accordingly.

Two sets of statistical comparisons provided information on the significance of treatment effects. Paired comparisons (two-way analysis of variance with the variance component among the sample plots as factor B and the "before and after treatment" representing the fixed effects factor A) between pre- and post-treatment fuel means indicated that thinning with either "whole-tree removal" or "stem removal — pile & burn" reduced significantly the small diameter fuel, litter, and depth at the 10% level (Table 1). In "thinning with stem removal — lop & scatter," statistically discernible reductions were detected only for litter and depth (along with large fuel) and not for small fuel (Table 1). Nested analysis of variance (with the study sites — random effects — nested within the slash treatments — fixed effects) for post-treatment (residual) large fuel loading, litter loading, and fuel depth was not significant at the 10% significance level, suggesting no difference among treatments; treatments did differ considerably in terms of residual small diameter fuel loadings.

The planar intercept sampling procedure can lead to imprecise results depending on transect placement (i.e., starting point, orientation, and length) and density of fuel particle intercepts in the area. Given these sources of variability in the fuel inventory estimates (Table 1), we have greater confidence that differences in hazard reduc-

tion due to treatment are best portrayed by simulated fire behavior before and after treatment (Figures 1-5).

Figures 1 through 3 exhibit fire behavior parameters (i.e., spread rates and flame lengths) of the custom fuel models constructed with pre- and post-treatment fuel data for each treatment. All of the thinning/slash fuel treatments seem to have an effect on predicted spread rates and flame lengths of a hypothetical surface fire. Under simulated severe fuel moisture and weather conditions, thinning and whole-tree removal reduced spread rates by more than one third and brought flame lengths closer to limits of direct attack methods from levels of serious control problems (Figure 1). Thinning with stem removal and lopping-scattering also managed to decrease fire behavior potential within levels of manual suppression means, but pre-treatment fire potential was relatively low in those locations (Figure 2). Thinning with stem removal and piling-burning minimized dramatically fire hazard and resistance-to-control, from levels of considerable suppression difficulties (Figure 3).

Surface fire potential (i.e., spread rate, heat per unit area, fireline intensity, flame length, area burned, and fire perimeter) was also statistically examined with two-way and nested analyses of variance. Reductions in fire potential were statistically significant ($p < 0.10$) in all three treatments (Table 2); residual fire behavior was not significantly different among treatments (Table 2).

Thinning and residue disposal took place concurrently, hence the actual amount of slash produced by thinning was impossible to measure directly. This amount of slash had to be estimated indirectly as described in Methods. On an average for both study sites, 5.2 t/ha of excessive small diameter woody fuel would have been produced by thinning alone without any slash treatment. Projected fire behavior for this hypothetical scenario portends levels of serious control problems with possible major fire runs and crown fires (Figure 4). For example, post-thinning fire potential (Figure 4) would have been 2 to 3 times greater than pre-thinning for midflame windspeeds varying from 0 to 30 km/h.

Crown fire potential was also decreased due to the treatments not only because of canopy removal (i.e., reducing aerial fuel), but also as a result of reduction in the amount of heat generated by surface fuels. According to Rothermel's (1991) crown fire nomograms and procedures, reduction in both aerial and surface fuels is translated into a lowering of flame lengths from 15 m to 10 m and heat output from 28000 kJ/m² to 18000 kJ/m² (Figure 5).

Discussion and Conclusion

In this study, thinning associated with three different slash treatments has shown to be an effective means for reducing fire spread, resistance-to-control, and ecological

THINNING / TREE REMOVAL

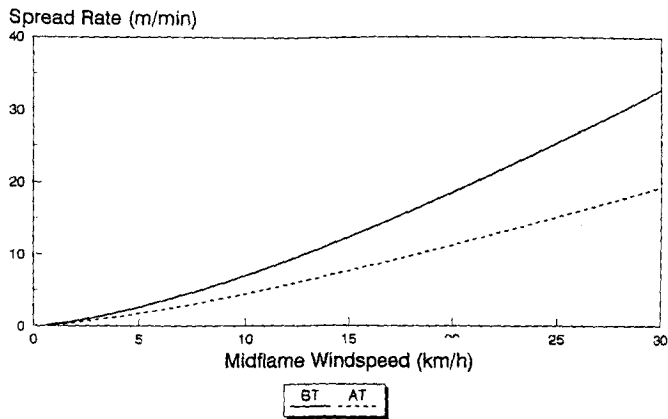
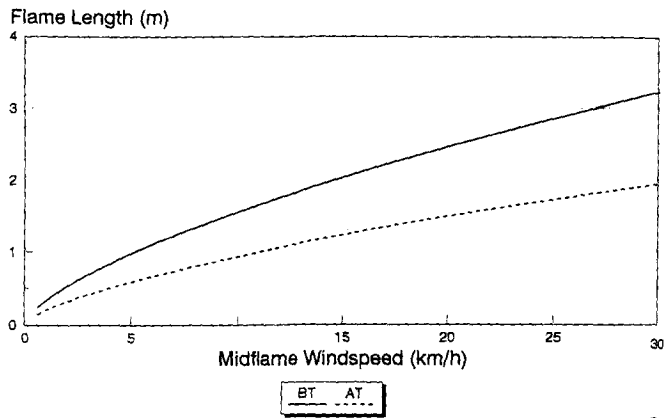
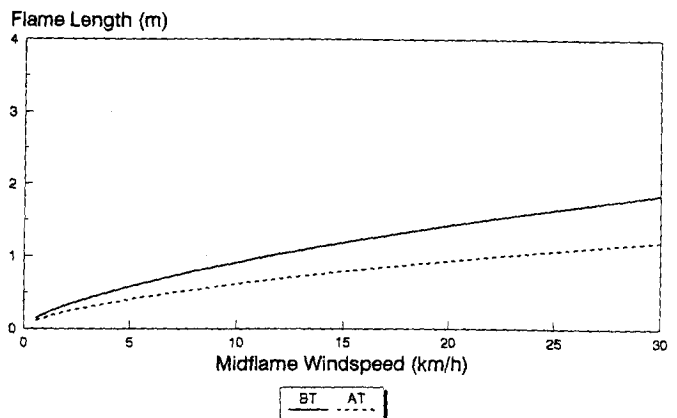
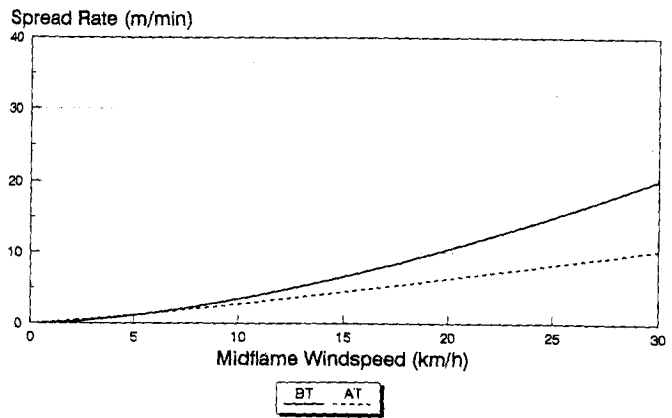


Figure 1. Simulated spread rates and flame lengths of pre-treatment (BT) versus post-treatment (AT) fuel profiles for thinning with whole-tree removal.



THINNING / LOP & SCATTER

Figure 2. Simulated spread rates and flame lengths of pre-treatment (BT) versus post-treatment (AT) fuel profiles for thinning with stem removal — lopping & scattering.



THINNING / PILE & BURN

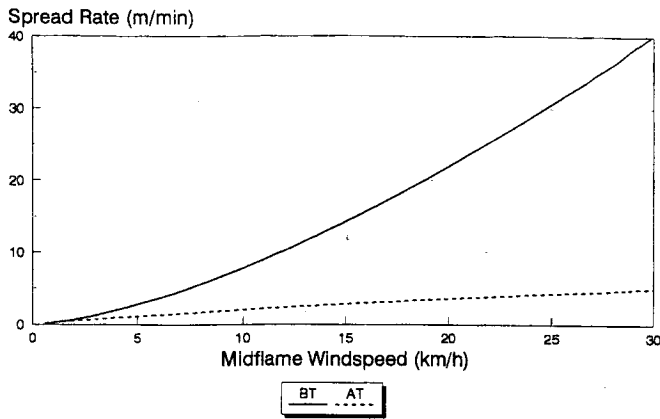
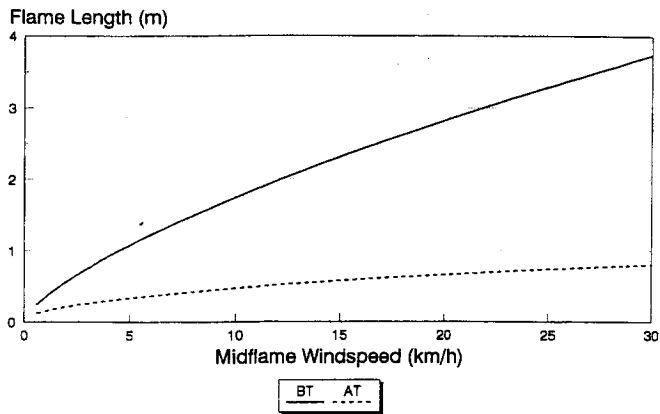
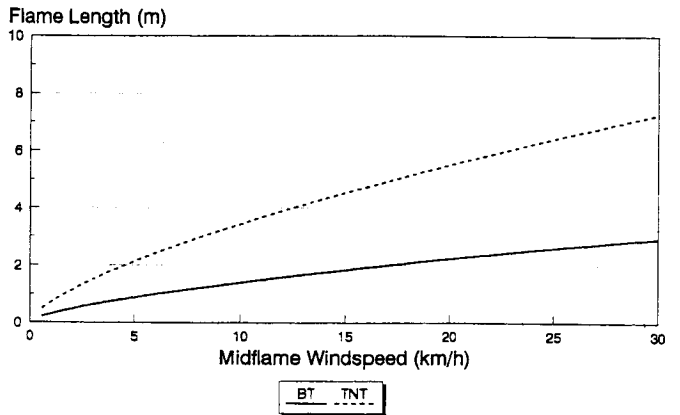
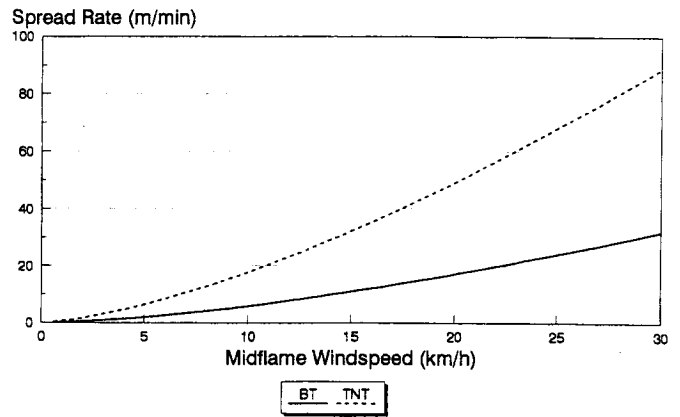


Figure 3. Simulated spread rates and flame lengths of pre-treatment (BT) versus post-treatment (AT) fuel profiles for thinning with stem removal — hand piling & burning.



THINNING / NO SLASH TREATMENT

Figure 4. Projected surface fire behavior for pre-treatment (BT) versus post-thinning/no slash treatment (TNT) average fuel profiles in the study area.



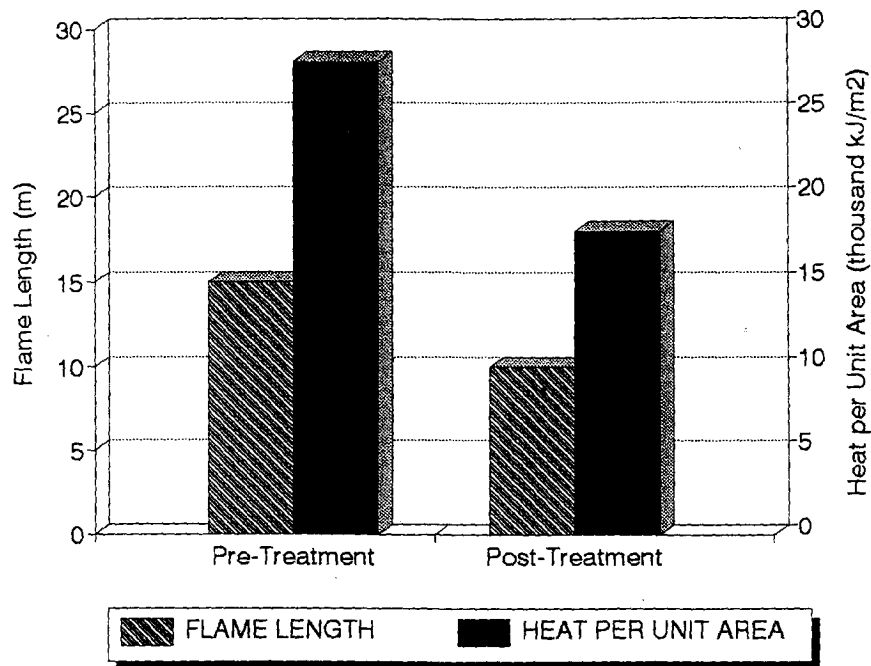


Figure 5. Crown fire potential for pre-treatment versus post-treatment average fuel profiles in the study area.

Table 2. Pre- and post-treatment surface fire behavior potential in Rocky Mountain National Park for each treatment (thinning with whole-tree removal; thinning with stem removal — lopping & scattering; and thinning with stem removal — hand piling & burning).

FIRE BEHAVIOR PARAMETER (unit)	TREATMENT					
	Tree Removal		Lop & Scatter		Pile & Burn	
	PRE	POST	PRE	POST	PRE	POST
SPREAD RATE (m/min)	10	6	7	5	12	2
HEAT PER UNIT AREA (kJ/m ²)	4561	2889	3474	2394	4646	1628
FIRELINE INTENSITY (kW/m)	1252	515	661	295	2279	82
FLAME LENGTH (m)	1.6	1.0	1.2	0.9	1.7	0.4
BURNED AREA ¹ (ha)	3.8	1.4	1.8	0.8	10.8	0.3
FIRE PERIMETER ¹ (m)	677	387	476	327	819	154

¹Elapsed time is 30 min.

losses. Modeled surface fire behavior was brought within limits of direct suppression techniques (Omi and Kalabokidis 1993) and potential damages were mitigated as a result of these alternative fuel treatments. Tree stem removal — accomplished in all three treatments — provided an extra benefit of utilizing unmerchantable wood, that would otherwise have been wasted.

Thinning with no slash modification treatment is an inappropriate option because more fuel becomes available for combustion and, thus, contributes to extreme fire outcomes (e.g., crowning and erratic fire behavior). Crown fire hazard was decreased as a result of the thinning/slash modification treatments due to removal of both aerial and

surface fuels, but crown fire potential still remained high.

Piling and burning was the most effective method of slash disposal in terms of predicted fire behavior but it is subjected to weather constraints similar to understory burning. Slash piles may be covered with paper or plastic for later burning under favorable conditions — when piles may be burned in cool seasons to minimize the danger of escaping fires and mortality of standing trees. The method offers an excellent alternative for treating areas that require extra care (e.g., viewsheds).

Whole-tree removal was also effective in reducing fuel hazards, requiring only appropriate yarding areas outside the forest stand where residues can be disposed

of when desired. The treatment provides a complete cleanup of the site; some disadvantages may arise from the total removal of biomass — and subsequent depletion of nutrients — from the ecosystem.

Lopping and scattering still managed to reduce fire behavior levels (mainly because of fuel depth reduction), but effectiveness of this treatment should be limited to light fuel accumulations — less than 20 t/ha (Wakimoto et al. 1988). In this method, branches are cut from the felled trees and scattered to reduce concentrations of fuels; if needed, slash is pulled away from residual green trees.

Recent catastrophic fires in Australia, southern Europe, and United States have illustrated forces of tremendous severity and complexity in the wildland-urban interface due to ecological and societal reasons. Urban spread into traditional wildland areas complicates fire management questions but does not negate effective answers. Management of fuels and prevention of human-caused ignitions are most promising for controlling wildfires and damage in the urban interface. These and other techniques of fuel management provide possibilities for proactively reducing hazards and developing “defensible space” (Dennis 1992) in the interface. Moreover, issues on relative costs and ecological impacts of fuel treatments need to be examined to conclude thorough analyses of the problem.

Acknowledgements. This research study was funded by the United States Department of the Interior under contract K910-A1-0001. The authors would like to thank the Rocky Mountain National Park staff for carrying out the fuel treatments and two anonymous referees for their recommendations and comments on an earlier draft of the manuscript.

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