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MANAGING FOREST FIRE FUELS IN THE URBAN INTERFACE

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SUMMARY

Alternatives to prescribed burning are needed for managing fuel profiles in forest ecosystems located within the so-called wildland-urban interface. From an ecosystem management perspective, understory burns may be desirable; however, sociopolitical and climatic constraints usually preclude implementation. The present study includes experimental fuel manipulations initiated along the Rocky Mountain National Park boundary interface with residential areas in Colorado, USA. Three thinning/slash fuel 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. Treatments were compared against thinning alone without any slash disposal and pre-treatment conditions. Statistical and graphical results indicate that treatments reduced surface fire behavior parameters, bringing them closer to limits of direct attack methods. Crown fire potential was decreased not only because of canopy removal, but also as a result of reduction in heat generated by surface fuels. Projected fire behavior for the thinning without slash removal scenario indicates serious control problems with major fire runs and crown fires possible.

INTRODUCTION

Fuel management becomes increasingly critical with adverse physical forces, increased fire risks, and unique resource values in forest ecosystems located adjacent to residential areas (the so-called wildland-urban interface). Fire managers often seek 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 usually preclude 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 high elevation parks where climatic regimes and/or anomalies limit the window for prescribed burning opportunities. The perplexity may have been accentuated in certain forests due to high fuel accumulations after decades of fire suppression.

Warm and dry summers desiccate forest biomass, adding to fuel stockpiles which accumulate over time and large areas due to epidemics (insect and disease) and other sources of disturbance. 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 efficiency of these practices as a means of reducing fire hazards.

These considerations are especially important in ecosystems of the western United States that are susceptible to large fire outbreaks, due to the prolonged drought, hazardous fuels, and annual lightning fire season. In the West, 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 several years ago in Mediterranean-type ecosystems (Green 1977; Omi 1977, 1979). A harvesting study in mature lodgepole pine (*Pinus contorta*) compared four harvesting and logging residue treatments with varying results (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.

METHODS

The present study was conducted on two high elevation forested sites at Rocky Mountain National Park (RMNP) in Colorado, USA (Figure 1). The first one is located along the southeast boundary of the Park adjacent to the town of Allenspark; the area contains a densely stocked lodgepole pine stand at 2650 m elevation, and shows an average of 30% slope with predominantly north-easterly through easterly aspects. The second study site is

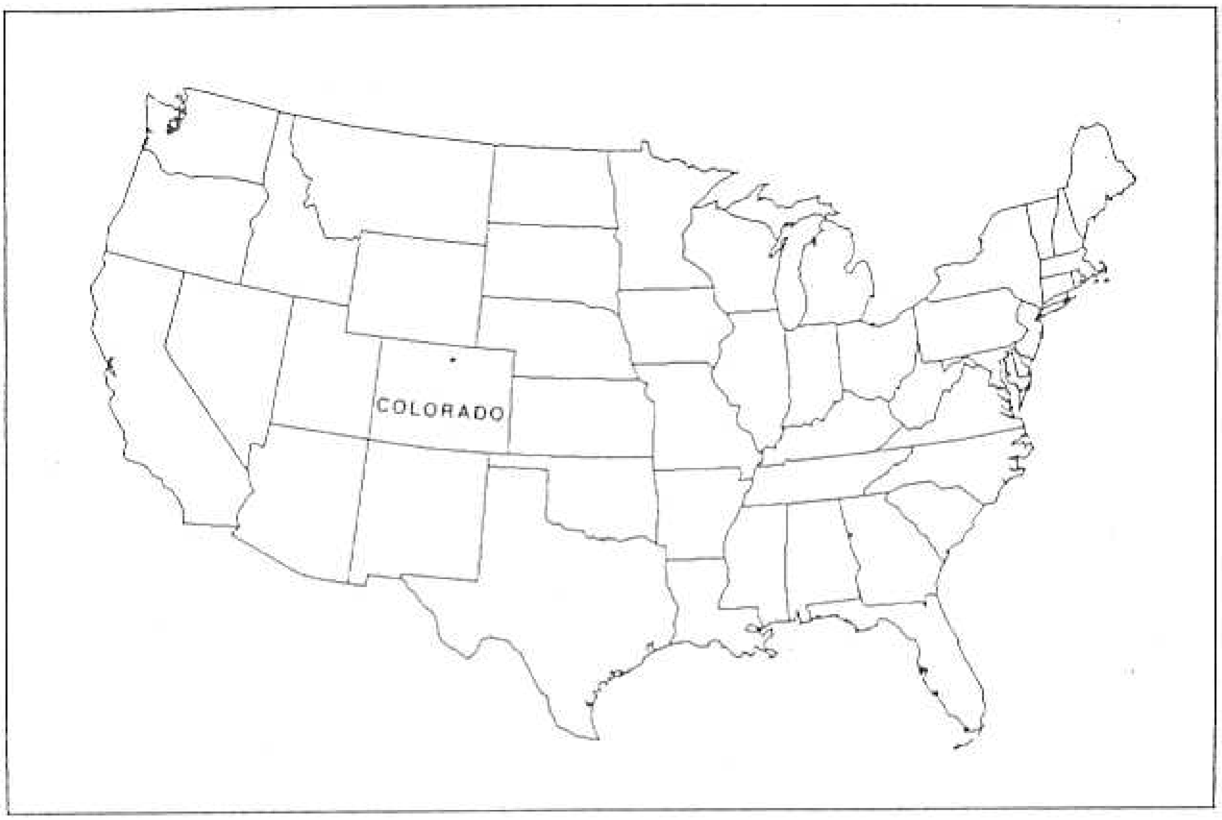

Figure 1. Rocky Mountain National Park's location in Colorado, USA.

located along the western Park boundary, adjacent to Columbine Lake residential area in the town of Grand Lake; the terrain is gently rolling at 2620 m elevation and is 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 about 400 to 300 trees/ha. Trees were felled by chain saws and bucked 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 have been hand-constructed in Treatment 3 not only to reduce fire hazard, but also to improve accessibility and appearance; the green slash piles were allowed to desiccate for a year before burning.

Inventory of downed fuels was based on the planar intersect technique (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 amount of slash that would have been produced by thinning with no slash treatment was predicted using the timber stand inventory, tables developed by Brown *et al.* (1977), and BEHAVE. Crown fire behavior was assessed utilizing crown fire nomograms, developed by Rothermel (1991), in conjunction with crown fuel tables (Brown *et al.* 1977).

Predicted fire flame lengths and spread rates for each fuel treatment (and the "no slash treatment" hypothetical scenario) were compared for the following environmental conditions:

1-h timelag fuel moisture	3 percent
10-h timelag fuel moisture	4 percent
100-h timelag fuel moisture	5 percent
Slope	30 percent
Midflame windspeed	0 - 30 km/h

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 40% of this fuel loading is made of litter, not woody, material. Grasses and shrubs were sparse and were not included in the inventoried fuel profile. The total fuel depth (high intercept) for the study area varied between 3 and 12 cm.

Two sets of statistical comparisons provided information on the significance of treatment effects. Paired comparisons (two-way analysis of variance) 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

Table 1. Pre- and post-treatment fuel inventory in RMNP for each treatment (thinning w/ whole-tree removal; thinning w/ stem removal--lopping & scattering; and thinning w/ stem removal--hand piling & burning). Within a row, means followed by the same letter are not different at the 10% significance level.

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

[1]*Total downed fuel < 7.5 cm in diameter.*
[2]*Total downed fuel > 7.5 cm in diameter.*
[3]*Litter layer consisted of needles, bark, and cone parts.*
[4]*Total woody and litter fuel depth.*

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 for post-treatment (residual) large fuel loading, litter loading, and fuel depth was not significant at the 10% significance level, suggesting no differences among treatments; treatments did differ considerably in terms of residual small diameter fuel loadings.

Figure 2 exhibits fire behavior parameters of the custom fuel models constructed with pre- and post-treatment data for average fuel conditions in the RMNP study area. 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, treatments reduced spread rates by more than half and brought flame lengths closer to limits of direct attack methods from levels of serious control problems. Reductions in fire potential were statistically significant ($p < 0.10$) in all three treatments; residual fire behavior was not significantly different among treatments.

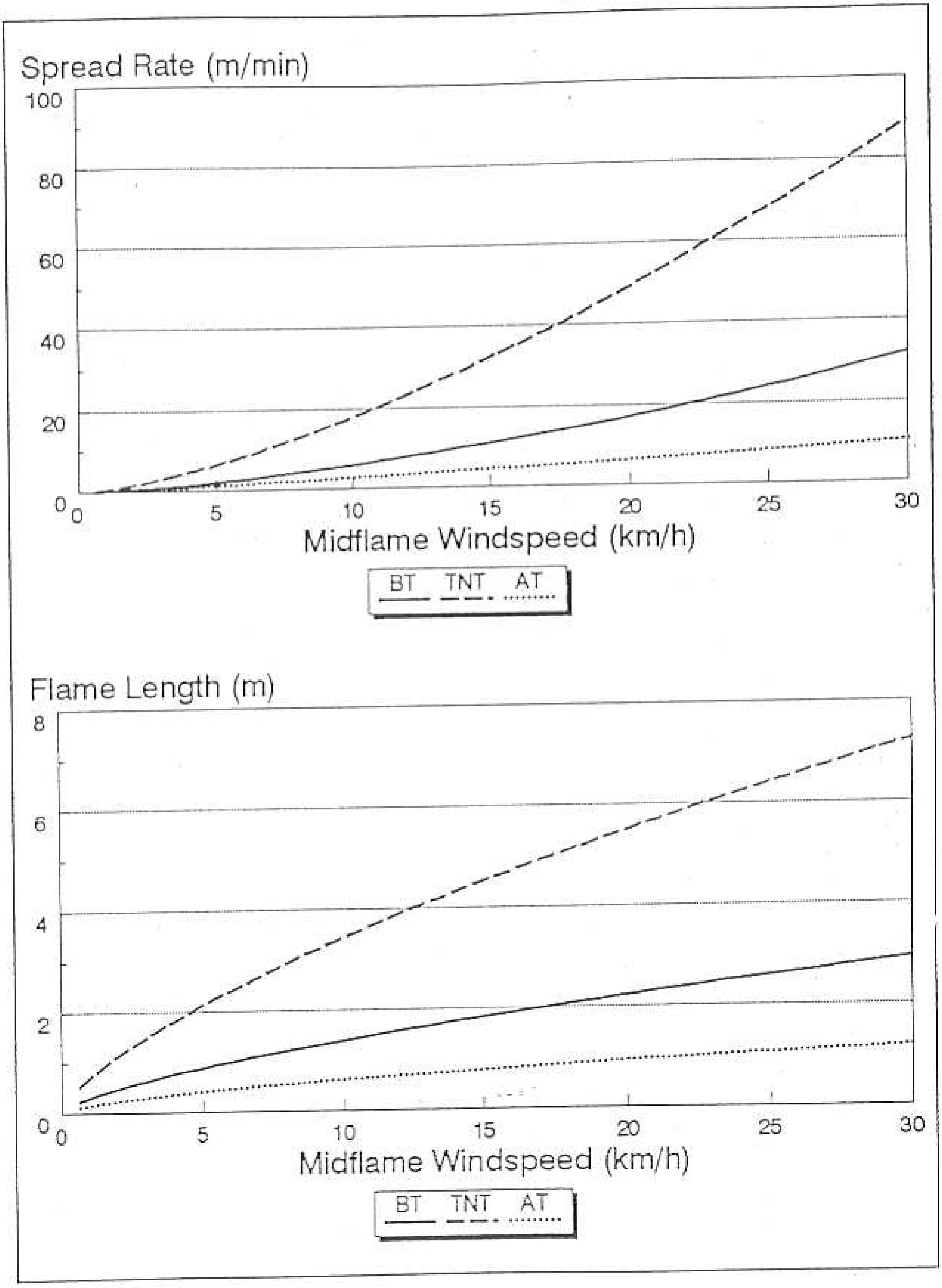

Figure 2. Predicted fire behavior for pre-treatment (BT), post-thinning/no slash treatment (TNT), and post-treatment (AT) average fuel profiles in RMNP.

About 6 t/ha of excessive small diameter woody fuel was 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. For example, post-thinning fire potential would had been 2 to 3 times greater than pre-thinning for midflame windspeeds varying from 0 to 30 km/h (Figure 2).

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. This reduction in surface fuels translates into a lowering of potential crown fire activity from about 15 m flame lengths and 28000 kJ/m^2 heat output to 10 m and 18000 kJ/m^2, respectively.

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 losses. Modeled surface fire behavior was brought within limits of direct suppression techniques 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 be 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 probably the most effective method of slash disposal but is subjected to weather constraints of 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). 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 hazardous fuels and prevention of human-caused ignitions hold the most promise for controlling wildfire activity and damage in the urban interface. These and other techniques of fuels management provide possibilities for proactively reducing hazards and developing "defensible" space in the interface. Issues on relative costs and ecological impacts of fuel treatments need also to be examined to conclude a thorough analysis of the problem.

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