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COMPUTER-AIDED COMPARISONS OF FUEL MODIFICATION TREATMENTS TO REDUCE LARGE FIRE PROBABILITY

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ABSTRACT: Little can be done to preempt wildfire activity by modifying weather or topography. However, potential exists to proactively modify the vegetative fuels in such a way as to eliminate or reduce eventual fire outbreaks. In the western U.S., different management and fuel treatment (mechanical, biological, chemical, and cultural) methods are being applied with insufficient and ecosystem-specific knowledge of their impacts on reducing large fire probability. A conceptual framework for analyzing fuel treatments must consider information on fire behavior and effects (including ecologic, economic, and scale indicators, with and without treatment). This framework is being applied to our present study in forested, shrub, and grass ecosystems. Fire hazards are evaluated by a combination of computer-aided comparisons for fuel treatments, management practices, and fuelbreaks. Computer modeling and simulation procedures allow integration of complex environmental data to evaluate the consequences of fuel management alternatives aimed at large-scale fire hazard reduction.

KEYWORDS: forest fires; fuel management; computer modeling; simulation

INTRODUCTION

Large fires recur with disturbing regularity throughout north America, primarily in the West. During the dry summer season in any given year we can assert with confidence that large, destructive, and costly wildfires will devastate some part of this region, although the location and timing of fire events are uncertain. The rich variety of vegetation in the West interacts with topography and climate to produce ideal fuel beds for recurrent and often spectacular wildfires.

Similar statements apply to other regions of the world where fire activity is promoted by fuel, weather, and topographic features. In such areas, the plant communities exhibit characteristic adaptations which allow certain species to persist in spite of, or even due to, repeated fires. Ironically, decades of fire suppression may have contributed to dangerously high fuel levels in certain areas.

TABLE 1. Fuel modification treatments used in the western United States.

FUEL TREATMENTS	
TECHNIQUES	EXAMPLES
1. DISPOSAL (on-site elimination)	Dozer or Hand Pile and Burn Broadcast Burning Natural Decomposition
2. REARRANGEMENT (on-site redistribution)	Lop and Scatter Crushing Chipping
3. REMOVAL (moving off-site)	Firewood Removal Farm Tractor Removal Yarding Unmerchantable Material
4. CONVERSION (changing flammability)	Vegetation Conversion Chemical Retardants Prescribed Fire
5. ISOLATION (breaking up continuity)	Fuelbreaks Firebreaks Green Belts

FUEL TREATMENTS: A POTENTIAL SOLUTION

Fuels modification in advance of fire outbreaks holds the most promise for reducing wildfire impacts, since weather or topographic attributes are not easily managed. Techniques for modifying fuels include reduction or removal of flammable materials, either through use of machines or crews, prescribed burning, or chemical/biological treatments (Table 1). These techniques have been used throughout the western U.S. during recent decades, though little information exists on the effectiveness of such treatments. Thus, traditional treatments have been applied with scant knowledge of anticipated reductions in subsequent wildfire activity; ecological impacts or effects specific to particular ecosystems are also poorly understood.

The absence of concrete information on treatment effectiveness can be explained from several perspectives. Productivity measures are elusive since fuel profiles may become more flammable with the passage of time, even if fuel volumes have been reduced successfully during initial treatment. After all, these profiles are merely reflective of biomass accretion and decomposition processes which occur naturally in plant communities. Further, the best test of a successful manipulation lies in subsequent reductions in wildfire activity (i.e., frequency, rate of spread, and intensity of subsequent fires), but an ignition may not occur to allow such a test. Even if an ignition occurs, the analysis of wildfire spread and effects will be confounded by spatial and temporal variations in the fire's environment, including fuel, topography, and weather changes. Finally, great uncertainties exist over the scale of treatments required to significantly reduce the likelihood of disastrous fire outbreaks. These problems suggest that fuel treatments might be assessed within a probabilistic framework.

USE OF COMPUTERS TO ASSESS FUEL TREATMENTS

Computer simulation provides a useful and informative alternative for assessing the productivity of fuel treatments. Computers have been used in many aspects of fire management, from monitoring weather patterns from remote satellite platforms to assisting with resource allocation decisions for managing on-going wildfire incidents. Figure 1 shows a conceptual framework that could be used for assessing the viability of fuel treatments. In the figure, the fire effects of societal consequence, such as size, cost plus loss, and ecological impacts, are a direct consequence of differential fire characteristics. The framework presents a convenient comparative analog to actual fires, since the impact of fuel profile changes should be borne out in the modeled behavior of subsequent fires. Further, the relationships embodied in Figure 1 could lend themselves to probabilistic assessment--although this has not occurred to date.

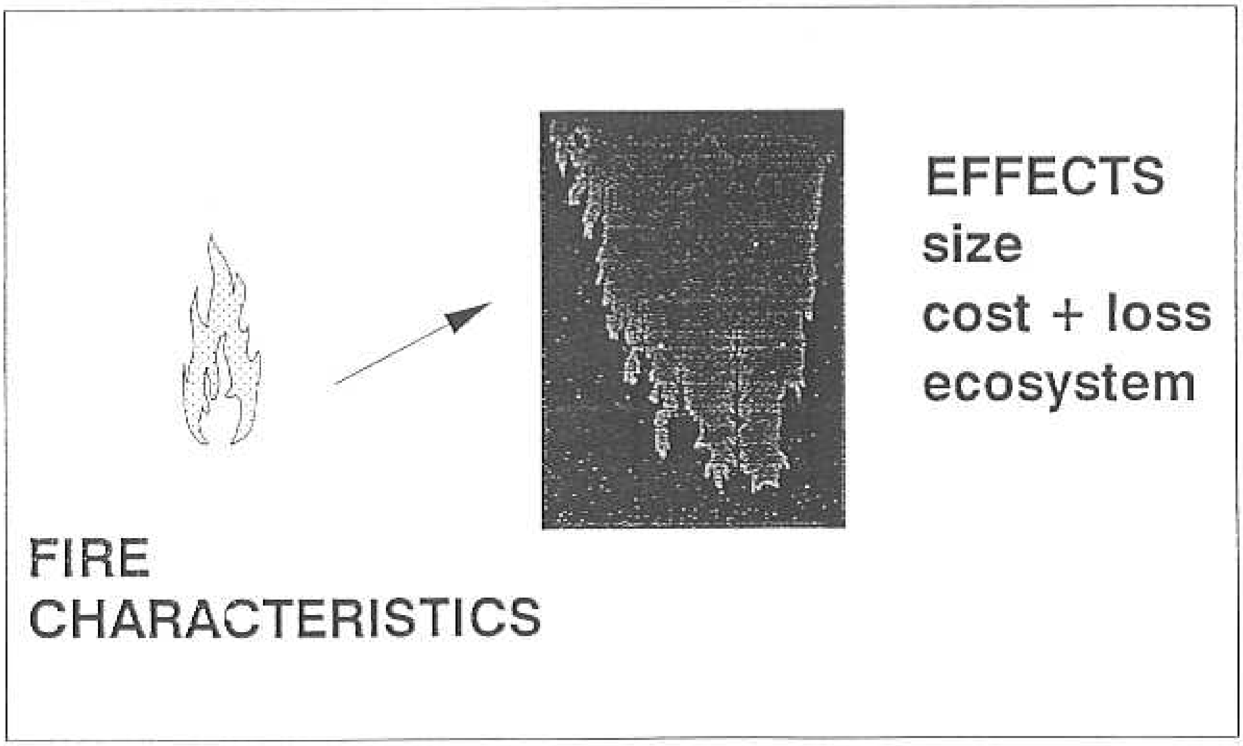


FIGURE 1. Conceptual framework for assessing fuel treatments, linking modeled fire characteristics to fire effects of interest.

Fire behavior is modeled using Rothermel's (1972) spread model as programmed into the BEHAVE computer system (Andrews 1986). Changes in fuel profile resulting from fuel bed manipulations can be simulated using the TSTMDL routine (Burgan and Rothermel 1984). Relative impacts in terms of difficulties encountered by suppression crews can be assessed using established guidelines (Table 2). With careful manipulation, the framework can also be used in other applications, such as assessing smoke dispersal (Ottmar et al. 1993) or predicting the effects of fire exclusion/inclusion in wildland ecosystems. With the advent of geographic information systems (GIS) capabilities, additional spatial analyses are possible at relatively low cost, including those which might lend themselves to display of probabilistic attributes.

APPLICATIONS OF CONCEPTUAL MODEL

We have applied this framework to provide point-estimates for computer-aided comparisons of fuels modification treatments in forested, shrub, and grassland ecosystems throughout the western U.S. (Table 3). In our study we are focusing on actual fuel treatments, where we conduct on-site experiments to directly modify fuels. Our study also includes comparative records analysis of management practices, to ascertain how resource management on a large wildland area affects fire potential. Lastly, our study assesses fuelbreak performances in reducing the potential of large fires.

For example, in Rocky Mountain National Park, Colorado, we have established replicable treatment plots to assess the differential impacts of thinning with whole-tree removal, thinning with stem removal and lopping/scattering of residuals, and thinning with stem removal and hand piling/burning of slash piles. In cooperation with the National Park Service, treatments were initiated along the Allenspark boundary in 1992 and will continue with implementation of alternative fuel management prescriptions in the next two years. Figure 2 illustrates the computer-based comparisons enabled by our study framework. As indicated in the figure, we would expect much higher spread rates and flame lengths--with serious control problems--if thinning slash is not reduced or removed from the site after treatment.

All management activities, including preservation, affect fuel complexes and eventual wildfire consequences. Assessment of management practices is illustrated by our prior study of fire potential on intensively- vs. extensively-managed lands within the Greater Yellowstone Area, following the notorious 1988 fires (see Omi and Kalabokidis 1991). Our comparative study of management practices was motivated by recognition of dramatic fire severity differences in mature forests as compared to recently-established forest plantations, where fuel disposal was included in the silvicultural prescription following timber harvest. Before going into the field, we simulated fire behavior in representative timber stands with different levels of understory slash, allowing depth to vary from 7.5 to 45 cm, as indicated in Figure 3. Our assessment of the higher spread rates and consequent fire intensities were borne out in our field measurements of fire damage in mature forest vs. regeneration sites (Figure 4).

The third feature of our study is illustrated by a previous analysis of fuelbreak performance in southern California by Omi (1977). In that study, burned areas of large wildfires were examined in terms of size of burn areas following fuelbreak encounters. The study indicated that the expected area burned depended on the presence and quality of

TABLE 2. *Fire suppression difficulties resulting from corresponding flame lengths and fireline intensities (converted to SI units, after Andrews and Rothermel 1982).*

FLAME LENGTH (meters)	FIRELINE INTENSITY (kilowatts per meter)	SUPPRESSION DIFFICULTIES
< 1.2	< 350	Fires can be attacked at the head or flanks by persons using hand tools Handline should hold the fire
1.2 - 2.4	350 - 1750	Fires are too intense for direct attack on the head by persons using hand tools Handline cannot be relied on to hold the fire Equipment such as pumpers, dozers, and retardant aircrafts could be effective
2.4 - 3.4	1750 - 3500	Fires may present serious control problems, for example torching out, crowning, and spotting Control efforts at the fire head will probably be ineffective
> 3.4	> 3500	Crowning, spotting, and major fire runs are probable Control efforts at the head of the fire are ineffective

TABLE 3. Design, selected areas, and participating U.S. land management agencies for each phase of the study.

PROJECT ACTIVITY [COVER TYPE]	TYPE OF DATA	LOCATION [AGENCY]
Fuel Treatments [Forested lands]	On-site Experiment	Rocky Mountain NP [NPS]
Fuel Treatments [Shrublands]	On-site Experiment	Craig District, Colorado [BLM]
Fuel Treatments [Grasslands]	On-site Experiment	Arapaho NWR, Colorado [FWS]
Management Practices [Forested lands]	Historical Records	Oregon [BLM]
Management Practices [Shrublands]	Historical Records	Dinosaur NM, Colorado [NPS]
Management Practices [Grasslands]	Historical Records	North Dakota [FWS]
Fuelbreaks	Historical Records	Idaho & Colorado [BLM & NPS]

BLM = Bureau of Land Management

FWS = Fish and Wildlife Service

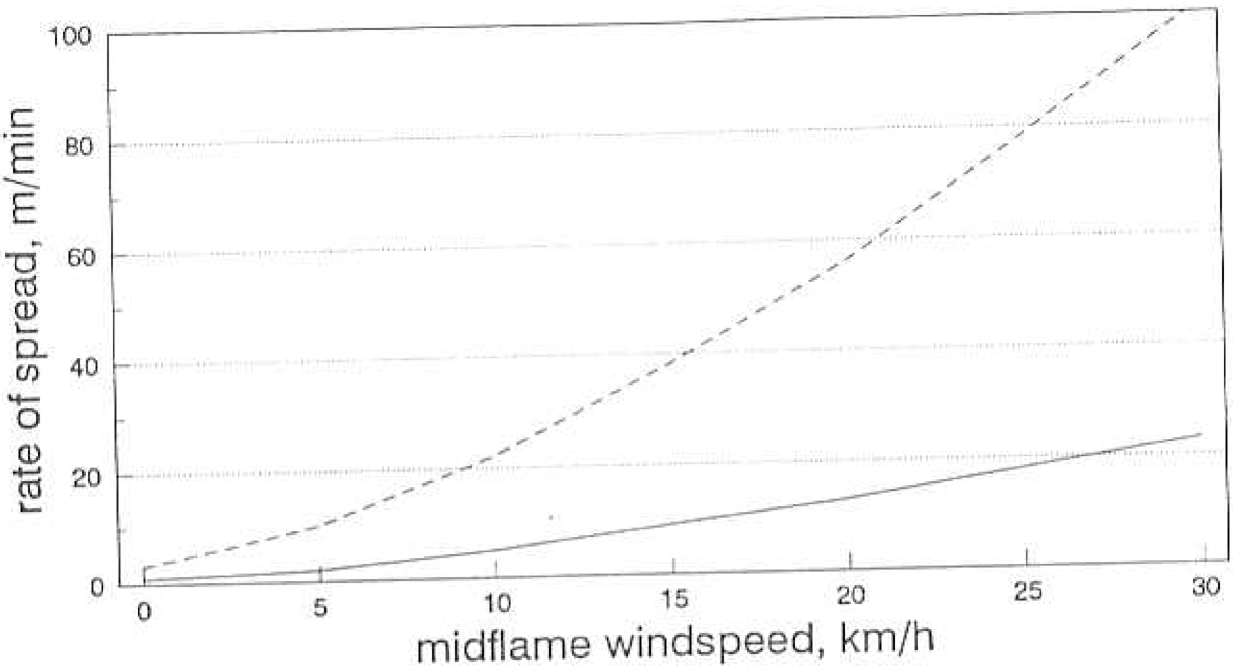
NPS = National Park Service

NM = National Monument

NP = National Park

NWR = National Wildlife Refuge

ROCKY MOUNTAIN NATIONAL PARK



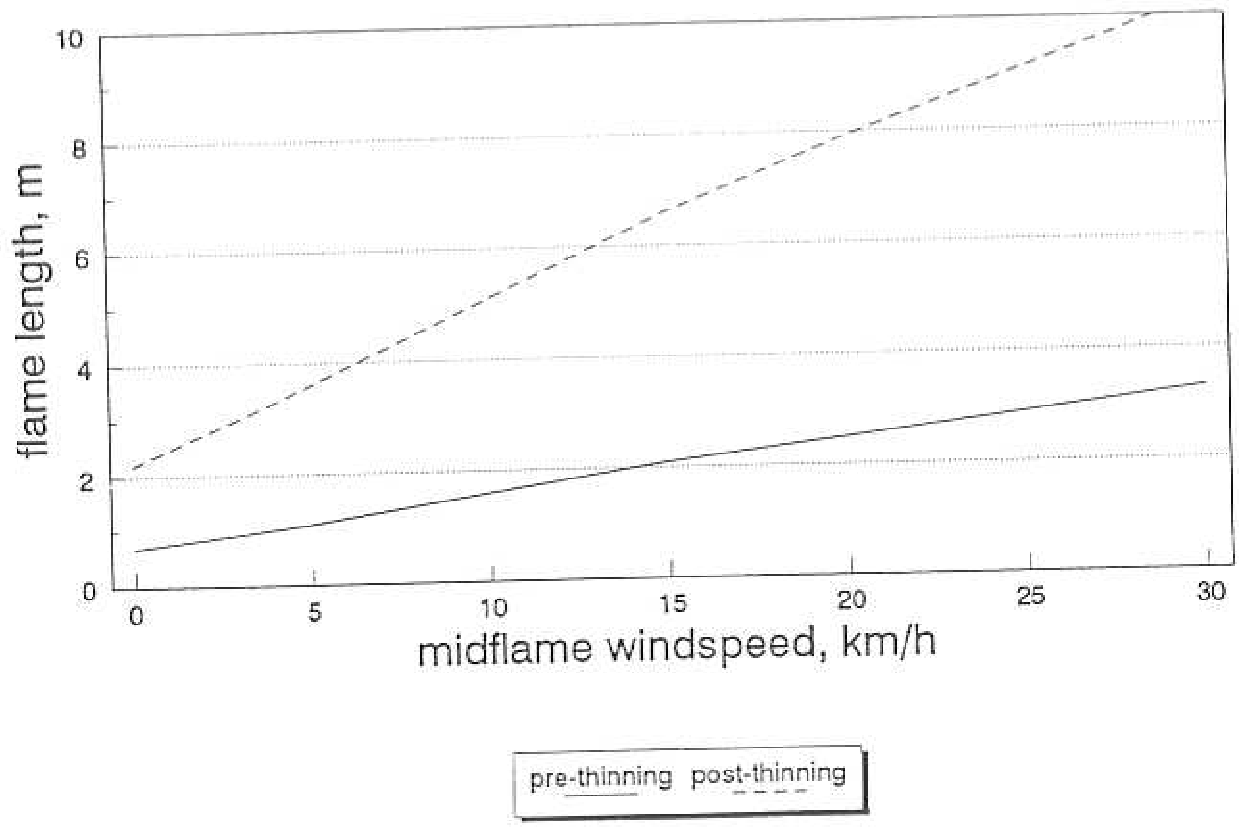


FIGURE 2. Fire behavior for existing pre-thinning and predicted post-thinning/no slash treatment fuel conditions in Allenspark, Rocky Mountain National Park.

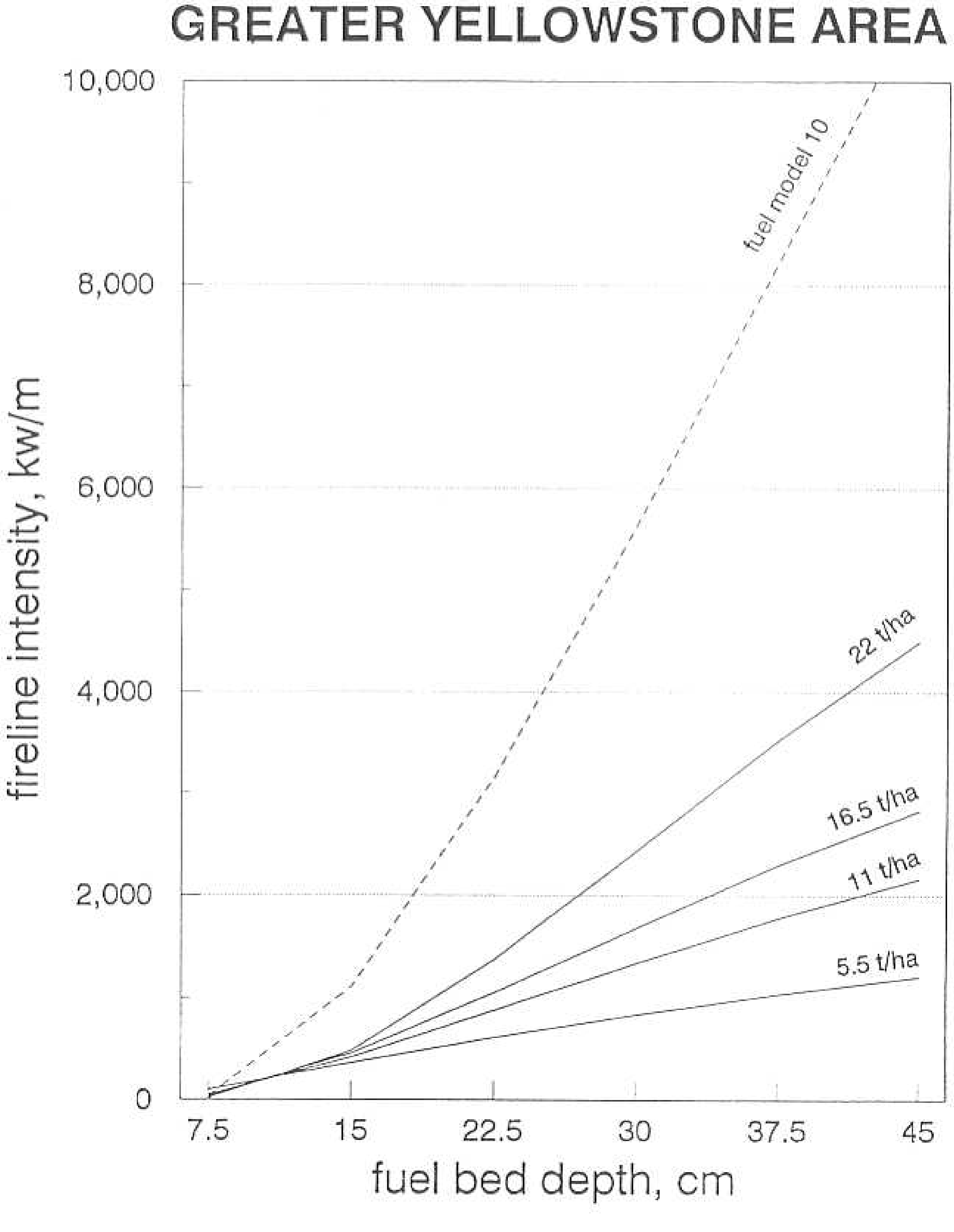


FIGURE 3. Simulated fireline intensities for representative fuel profiles in the Greater Yellowstone Area.

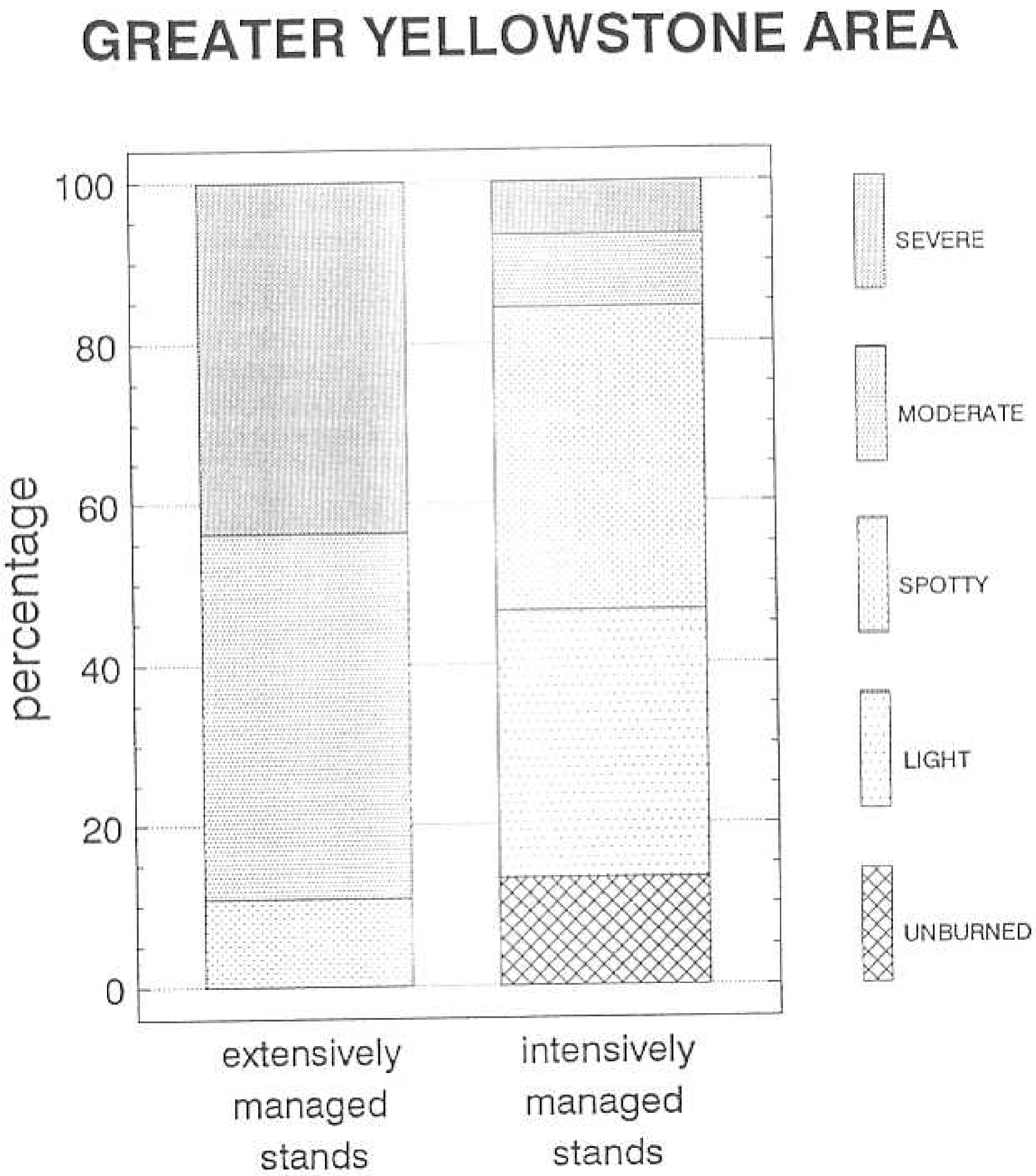


FIGURE 4. *Distribution of fire damage ratings on extensively managed (mature forest) vs. intensively managed (forest regeneration) sites in the Greater Yellowstone Area (after Omi and Kalabokidis 1991).*

fuelbreaks constructed and maintained in southern California watersheds. In general, we hypothesize lower expected burn areas when a comprehensive fuelbreak system is installed and maintained. Further reductions in area burned can be expected with treatment of the vegetation mosaic between fuelbreak segments.

SUMMARY AND CONCLUSIONS

In all three phases of our study we have used computer modeling to evaluate the consequences of fuel management alternatives aimed at large-scale fire hazard reduction. Each application has required a different perspective on fire characteristics: from modeled fire behavior in the assessment of actual treatments; to comparisons of modeled treatment to observed fire severity in our assessment of management practices; to analysis of burned area maps undistinguished by fire behavior in the study of fuelbreaks. Our conceptual framework allows and encourages this flexibility, and this flexibility is, in fact, a desirable outcome from our study. Other anticipated outcomes include analytical tools and processes to assist in evaluation of a broad range of fuel management alternatives.

As computers become smaller and more powerful, so do their analytical uses and potential applications. Even so, the use of computers is not without limitations. For example, the underlying physical and biological relationships must be developed and verified before they can be encoded into a computerized framework, such as presented here. Although existing fire models provide point-estimates for characterizing the growth and effects of large fires, we also recognize that fire must be considered within a probabilistic framework, owing to its highly variable effects as it spreads over an ecosystem or through a residential subdivision. These procedures allow incorporation of diverse environmental information as aids to decision-making and planning which ensure public safety, manage natural resources, and yet allow fire to play a beneficial role in ecosystem management.

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