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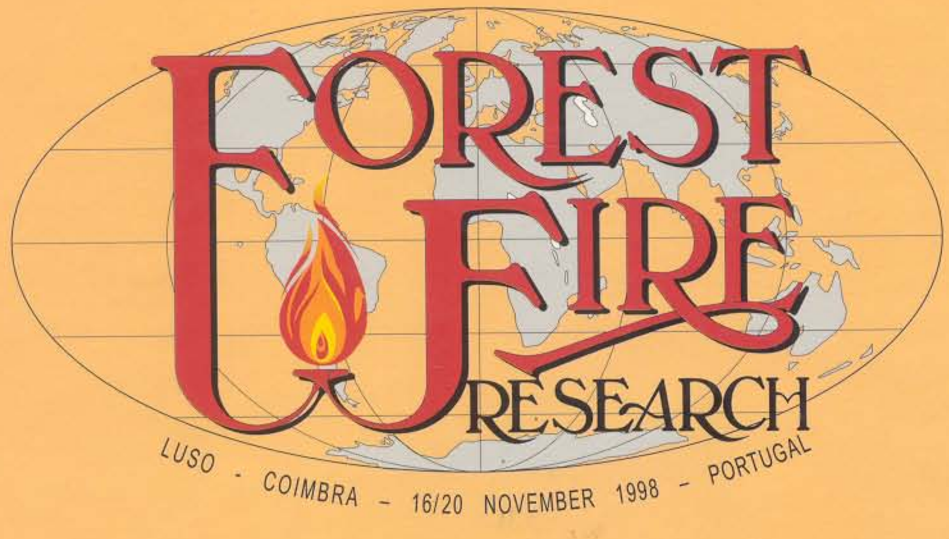

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FUELS MODIFICATION TO REDUCE LARGE FIRE PROBABILITY

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SUMMARY

Studies of actual fuel treatments, fuelbreaks, and management practices provide insight to possibilities for reducing the likelihood and consequences of large fires. Site-specific fuel treatments such as mechanical crushing, lop and scatter, physical removal, and prescribed fire can reduce the likelihood of large fires, though the effect is localized to the treatment area. Prescribed fire, in particular, has captured considerable attention due to recent proposals for expanding its use in western wildlands. Its biggest advantage is relatively low cost, yet concerns with smoke may represent the biggest impediment to widespread application. Fuelbreaks provide anchor points for management units and may serve as a transition between discrete fuel projects and management practices. Management practices such as grazing management, timber management, and ecosystem management affect larger areas than discrete fuel treatments, depending on the type, magnitude, and longevity of fuel reductions effected. Ultimately, changes in management practices hold the greatest promise for reducing large fire probability. Fire exclusion has had greater impact than any other single management practice (with the possible exception of livestock grazing). Ultimately a combination of fuel treatment strategies applied over a landscape will provide the greatest security against large fires, although there are no perfect guarantees that large fires can be prevented.

RATIONALE

Though relatively infrequent when compared to the total number of fires that occur, large wildfires usually cause significant ecological, economic, and socio-political impacts. The scale and clustering of large fires, such as those observed in the Greater Yellowstone Area (1988) and episodic fire outbreaks in the western US (e.g., 1994 and 1996), increase the extent of ecological impact. Further, these large fire episodes tend to occur during prolonged droughts, with resultant fire severities that portend greater consequences for natural resource sustainability. Economically, large fires account for a disproportionate share of the annual cost and losses due to wildfires. The socio-political fallout from large fires can become intense, especially when media focus on human casualties, property loss, or business disruptions. Public sentiment toward natural resource losses in high-profile park or recreation areas may contribute additional interest.

Large fires merit special consideration due to their scale (burned area) and consequent ecological, economic, and socio-political impacts. The mechanisms associated with large fires are conceptually straightforward (Deeming 1990): flammable materials (*fuel*) are exposed to an intense heat source (*firebrand*) coincident with conducive weather and fuel conditions (*fire danger*). Reduction of large fire probability thus can focus on one or both of two strategies: 1) elimination or reduction of firebrand sources (risk management); or 2) removal or modification of the fuel to reduce its flammability during high or extreme fire danger conditions (hazard management). Costs are exacerbated on large fires due to the high costs of mobilizing suppression resources and organizing management teams from across the country. By contrast, prescribed fire costs are lower since treatments are conducted with pre-specified objectives under a favorable burning prescription, thus facilitating managerial control over fire size and severity.

APPROACH

We evaluated fire hazard reduction in forested and rangeland ecosystems from three perspectives: 1) actual fuel treatments, with on-site experiments to directly modify fuels; 2) construction and maintenance of fuelbreaks to reduce the potential of large fires; and 3) management practices to reduce fire potential over a large wildland area. Scientists and practitioners have long-recognized that fuels, topography, and air mass are the chief determinants of wildland fire behavior and severity, and that of these, only fuels can be managed. The focus of this study has been the strength and limitation of various techniques. Actual treatments involve manipulation of the vegetation through individual projects in a particular site. Management practices usually involve implementation of policy, including a series of projects conducted over a large area and extended time frame. Fuelbreaks bridge the distinction between actual treatments and management practices; discrete segments may provide defensible fuel profiles on individual projects or as part of a larger network for managing an entire landscape.

In this paper we highlight specific examples of actual fuel treatments, fuelbreaks, and management practices. We conclude by discussing implications for managing fuels over an entire landscape.

ACTUAL FUEL TREATMENTS

Kalabokidis and Omi (1998) analyzed the effectiveness of fuel treatments in forested areas of Rocky Mountain National Park, CO by conducting fuel inventories and simulating fire behavior in treated versus untreated stands. Treatments analyzed were: thinning with whole tree removal; thinning with stem removal--lop and scatter; and thinning with stem removal--hand pile and burn. In summary we found that all the thinning treatments reduced modeled surface fire behavior closer to the limits of direct attack methods. Thinning treatments reduce crown fire potential, not only because of canopy removal, but also due to reduction of the surface fuels. Removal of understory fuels, including thinning slash, is important since crown fire behavior may be initiated or linked to surface fire intensity (Van Wagner 1977).

We also examined prescribed fire projects in the western US. Prescribed fire has long been touted as a useful tool for achieving a variety of objectives. Numerous judgments are required to assess the overall effectiveness of treatments, including impacts on subsequent fire behavior and costs. Table 1 provides a summary relative to the actual treatments studied on this project.

Table 1. Summary of treatment effectiveness based on modeled rate of spread (ROS) and flame length (FLAME) changes due to actual fuel treatments (Rocky Mountain area). Unit cost estimate ranges (US$) are from Caplinger (1996).

TREATMENT/ INDICATOR	THIN, REMOVE WHOLE STEMS	THIN, LOP & SCATTER	THIN, PILE AND BURN	RX FIRE
ROS	decrease ~40%	Decrease ~30%	Decrease ~80%	Decrease 10~95%
FLAME	decrease~40%	Decrease ~25%	Decrease ~75%	Decrease 10~95%
COST ($/ha)	3700-6200	3700-6200	3700-6200	125-270

The cost estimates in Table 1 are from California, but magnitudes are representative of reasonable ranges of unit cost/ha expenditures in the western US. Based on modeled surface fire behavior, thinning with piling/burning seems to reduce rate of spread and flame lengths most consistently, followed by thinning with whole tree removal and thinning with lop and scatter (Kalabokidis and Omi 1994). Lopping and scattering redistributes fuels within a stand, which can actually increase fuelbed continuity and consequent spread characteristics. Burning alone produces the most variable hazard reduction, depending on the whether the fire is ignited on "hot" versus "cool" ends of the prescription window.

Based on unit treatment costs ($/ha), burning is clearly least expensive in terms of implementation costs (Table 1). Yet as with other treatments, the total cost of prescribed fire has many facets, including direct costs (inventory, site preparation, burn implementation, and monitoring/evaluation), and indirect costs (support and overhead). Some costs may be fixed and remain unaffected by level of activity; others may be variable, increasing or decreasing as the size of the burning operation becomes larger or smaller (Cleaves and Brodie 1990). For all treatments, overall impacts on cost plus net value change will depend on the values-at-risk and treatment scale.

Fire potential was assessed in piñon-juniper areas subjected to fuel modification on Chapin Mesa, Mesa Verde National Park, CO. A fuelbreak was constructed during 1993-95 by handcrews using chainsaws. Table 2 displays surface dead fuel inventory estimates in treated (fuelbreak areas) versus adjacent untreated areas. The data suggest lower levels of dead fuels on fuelbreaks compared with adjacent untreated areas, especially in the total, 10-hr and large fuels categories (solid and rotten). The high coefficients of variation (ratio of standard deviation to mean) inferred from the table indicate the patchiness of fuel distribution on both treated and untreated plots.

Table 2. Surface dead fuel estimates (tonnes/ha) by size class and category for untreated and fuelbreak areas, based on inventory transects, Chapin Mesa, Mesa Verde National Park (standard deviations parenthesized).

Size class/category	Fuel loadings in untreated areas, tonnes/ha (n=8)	Fuel loadings in fuelbreak areas, tonnes/ha (n=8)	Significance
1-hr	0.13 (0.04)	0.13 (0.09)	.47
10-hr	3.41 (2.24)	2.04 (1.21)	.08
100-hr	3.38 (4.98)	3.29 (3.92)	.48
1000-hr (solid)	19.86 (31.96)	2.69 (4.98)	.09
1000-hr (rotten)	7.28 (13.47)	0.25 (0.72)	.09
Total dead, downed	34.06 (29.83)	8.40 (7.55)	.02
Litter	8.74 (13.20)	9.12 (10.78)	.48
Total dead fuel (dead, downed, litter)	42.80 (37.98)	17.52 (14.07)	.06

Table 3 shows significant structural differences between the untreated and fuelbreak areas based on density (#trees/ha) and basal area (m^2/ ha). The most striking differences were due to removal of overstory and understory trees, resulting in higher spacing between tree crowns, reductions of needle loads, and area coverage by surface fuels on the fuelbreak. Basal area was reduced by almost 45% (13.7 m^2/ ha), while tree density was reduced by 71%

(829 trees/ha), as inferred from Table 3. These differences confirm further that the treated or thinned stands generally possessed greater spacing between overstory trees, fewer overstory trees, and less understory plants. Along with the lower surface fuels (Table 2), the fuel discontinuities created in treated areas should enhance future options during wildfire events.

Table 3. Basal area (m^2/ha) and density (trees/ha) on transects placed in untreated vs fuelbreak (thinned areas) on Chapin Mesa, Mesa Verde National Park. The thinning of trees on the fuelbreak dramatically reduces both basal area and density.

Stand Characteristic	Untreated (n=3)	Fuelbreak (n = 4)	sig. *
Basal area (m^2/ha)	30.7	17.0	.10
Density (trees/ha)	1161.0	333.8	.009

* one-tailed test

Types of crown fire expected at various wind speed-crown fuel load combinations in untreated stands are shown in Table 4, based on Rothermel (1991). During no-wind conditions, crown fires may not develop even at high crown fuel loadings. Convection-driven fires crown-fires are more likely at windspeeds between 15-30 km/h. Wind-driven crown fires become more likely in sparse tree crowns at higher wind speeds. Existing techniques could not be used to model the likelihood of fire spreading across the fuelbreak, although the reduced basal area and tree density in the thinned areas should greatly reduce the severity of any fire which encounters the break. Under high wind conditions, spot fires could be transported across the fuelbreak. Even so, the effect of thinning would be to dramatically reduce the severity of burning conditions (as compared to adjacent untreated areas).

Periodic high intensity crown fires characterize the piñon-juniper fire regime in Chapin Mesa. The regime is unique in that under most circumstances a fire may hardly carry through the fuelbed, especially in the absence of high winds. The Chapin Mesa fuelbreak is more likely to slow the spread of an oncoming fire at lower wind speeds. Fuelbreaks in general are not designed to stop a fire's spread but to provide options (e.g., firefighter access and egress, and back-fire possibilities) for managing large fires, as well as providing anchor points for igniting prescribed burns prior to wildfire occurrence. Conceivably the fuelbreak should provide defensible fuel options so long as basal area stays well below about 20 m^2/ha, tree density below 500 trees/ha, and surface and crown fuels each below 2 tonnes /ha, even during drought conditions. Adjacent untreated fuels would support the types of crown fire noted in Table 4, and these crown fires could breach the fuelbreak if driven by higher loadings/windspeeds. The fuelbreak alone might not stop fires under all conceivable circumstances; however, it will provide options for taking a stand against an oncoming wildfire.

Table 4. Modeled crown fire behavior for various wind speed and crown fuel load combinations, based on Rothermel (1991).

6-m windspeed (km/hr)	1-12 tonnes/ha	13-24 tonnes/ha	25-35 tonnes/ha	36-45 tonnes/ha
0	crown fire not likely	crown fire not likely	crown fire not likely	crown fire not likely
16	convection-driven	convection-driven	convection-driven	convection-driven
32	wind-driven	convection-driven	convection-driven	convection-driven
48	wind-driven	wind-driven	convection driven	convection driven
64	wind-driven	wind-driven	wind-driven	wind/convection-driven

MANAGEMENT PRACTICES

For our third perspective, we examined historical fire records from Dinosaur National Monument to provide a comparative analysis of management practices. Information sources examined for relevancy to large fire potential included: fire occurrence, ignition source, management practices, and fire weather.

Maps and file records from Dinosaur National Monument were digitized into ARC/INFO GIS software and used to examine the explanatory power of up to 11 independent variables during the time period 1940-92 in terms of explaining probability of fires greater than 4ha (10 ac). Four different equations were examined, two of which showed the significance of the grazing variable. Coefficients for these four models are presented in Table 5.

Using the ARC/INFO GIS, the 11 explanatory variables and one dependent variable were overlain to build a new coverage in which the initial polygons had been split up so as to delineate new ones that differed from surrounding polygons in at least one of the mentioned variables. The resultant coverage contained 138,169 polygons of which 10,424 had been burned at least once, with the remainder unburned during 1940-92. These new polygons were treated as homogeneous geographic units for the statistical analysis.

Ten percent of the unburned polygons were randomly sampled and used with the burned polygons in the statistical analysis, for a total of 23,351 cases. The signs and magnitudes of the regression coefficients in Table 5 provide an indication of the impact of the independent variable on wildfire probability. The probability for each unit burning by unplanned fire, p_i, was calculated by the logistic function

$$p_i = \exp(u_i) / (1 + \exp(u_i)) \qquad (1)$$

where u_i are dependent variables for the logistic regression equations represented by the coefficients in Table 5 ($i = 1,2,3,4$).

Table 5. Logistic model coefficients and percentage correct classifications (PCC) with statistical significance for explaining the probability of historic fire activity, including the influence of grazing impact (variable AUM) in Dinosaur National Monument.

Variable	Model 1	Model 2	Model 3	Model 4
Annual Precipitation (mm)	.0065	-0.0177	-.0162	
Avg. Animal Unit Months	-4.2726		.9719*	
Fire Behavior Potential	.1077*	.3560	.4207	
Mean Fire Season Precipitation (mm)	.0174	-.0077	-.0077	
Mean Fire Season Relative Humidity (%)		.0194	.0190	
Mean Fire Season Max Temperature (^{0}C)		-.3179	-.2921	-.3385
Max July Windspeed (mph)	-.1279	-.1606	-.1634	-.1496
Max July Temperature (^{0}C)		-.2764	-.2526	
Mean July Windspeed (mph)			.0123	
Mean Fire Season Windspeed (mph)			.0383*	
Slope	-5519	-.6414	-.6525	-.5227
Constant	-1.5235	24.8579	22.7762	11.7571
PCC	65.30	67.77	67.92	68.10

* not significant at 5%

Models were used to map probabilistic fire danger in DNM into four classes of fire danger: low, medium, high, and extreme. All four models showed high classification correctness over 65%; model 2 (with 8 independent variables) explained more than 2/3 of fire activity in the area with the least number and a wide spectrum of relative variables, whereas model 4 with only 3 environmental variables (i.e., temperature, wind, and slope) had the highest PCC. Most of the historical fires in the last 50 years burned within the classified high- to extreme-danger areas of DNM and justified the high precision levels of the analysis. These probabilistic fire danger models/maps have experimentally validated the important parameters that control fire activity; in addition, availability of quantitative fire danger maps provide for *a priori* spatio-temporal determination of high danger zones, maximizing the efficiency of fire management with the least possible cost.

In a related study, Romero (1997) developed a method by which changes in fire potential over space and time could be identified and related to changes in prevailing management actions. In this way he could examine the effect of management practices (i.e., fire management and livestock grazing) on fire potential. He examined the probability of an unplanned fire burning in the same 16,844 ha (41,620 ac) study area, but split the historic fire record into three time periods (spanning 33 years), also using multiple logistic regression. Accordingly, livestock grazing reduced fire potential at the higher livestock stocking levels found in the first era (1960-79). The second era (1980-85) experienced a dramatic increase in "high risk" areas (odds of burning greater than 1/50), due to grazing reduction but also the initiation of prescribed natural fire in the study area. No obvious changes were detected between areas grazed at lower rates and ungrazed areas in the third era (1986-92), perhaps due to the poor growing conditions brought on by extreme drought during this period. Romero (1997) also found that fire occurrence probabilities might increase in sagebrush areas burned previously by wild or prescribed fires. In such areas, the type conversion to grass might temporarily support higher fire potential due to higher fine fuel loadings after burning.

DISCUSSION

Actual Fuel Treatments

All treatments that remove biomass can be effective in reducing fire hazard, but fuels must be managed with an eye toward overall resource and ecosystem objectives for an area.

The most cost-effective treatments will be those which are consistent with land management objectives. Where wildfire incidence is high, treatment costs are low, and values protected are high, then actual fuel treatment projects may be justified (Deeming 1990). In other circumstances, other alternatives such as management practices or fuelbreaks may prove more cost-effective either in combination with, or as alternatives to, actual fuel treatments.

Prescribed fire may be the most versatile (and lower cost) treatment alternative but also produces the most variable effects. It also may be the most logical treatment in fire-adapted or fire-prone ecosystems. In other situations, combinations of treatments (e.g., thinning, slash disposal, then understory burning) may make more sense, especially in areas with high fuel concentrations or where fuels have accumulated due to fire exclusion policies of the past century. In such areas, mechanical treatments may be necessary to reduce surface fuels and stand basal area, prior to burning.

The biggest drawbacks to widespread application of prescribed fire may be the effects of smoke. Most prescribed fires have the potential to degrade ambient air, impair visibility, and may expose the public to possible health risks. Public opinion about smoke is generally negative due to the degradation in ambient air quality, especially in parks or pristine areas. Visibility impairment can have serious economic consequences as well: highway deaths and airport closures have been attributed to excessive smoke from wild and prescribed fires. Further, smoke particles contain compounds known to be mutagenic, and in some cases, carcinogenic. Human reactions can vary from airway constriction to cancer, although most evidence is anecdotal (Morgan 1989). These negative impacts conflict with state and national air quality regulations, even though much more smoke is produced from wildfires than prescribed fires (Huff and others 1995). Ironically, smoke from wildfires is not regulated while prescribed fire emissions fall under state regulations promulgated under the federal Clean Air Act and subsequent amendments.

Incomplete information on the chemical and physical properties of smoke restricts complete understanding of the risks to air quality and human health from wild and prescribed fires. Scientists and managers need to educate publics about tradeoffs between prescribed fires, wildfires, ecosystem health, visibility degradation, and public health problems from exposure to smoke (Huff and others 1995).

The above problems and contingencies lead some to conclude that evidence of cost-effectiveness for prescribed fire is largely anecdotal and unsupported by estimates of decline in control costs and/or damages associated with fuel treatment (Gorte 1995). Still, compared to mechanical or labor-intensive, prescribed burning costs may be far more reasonable. Few studies have compared prescribed fire costs with activities such as logging, pruning, or thinning, where revenues from biomass removal may offset treatment costs.

In spite of difficulties, there certainly is a place for prescribed fire projects in reducing large fire probability, but it is unlikely that burning alone will solve all hazard abatement problems over an extensive area. A variety of treatments may be required prior, and in addition, to fire. Further, the other benefits and costs attributable to fire need to be factored into the cost-effectiveness equation. In short, we need to think beyond individual projects to considering an entire fuels management program, including landscape treatments.

Fuelbreaks

There will always be a role for well-designed fuelbreak systems which provide options for managing entire landscapes, including wildfire buffers, anchor points for prescribed fire, and protection of special features (such as urban interface developments, seed orchards, or plantations). In this context, fuelbreaks and prescribed burns should be viewed as complements to one other, rather than as substitutes.

Well-conceived fuelbreak systems have a role in today's deliberations about sustaining forest health and ecosystems, just as they did when fire exclusion was the dominant paradigm. Back then, fuelbreaks were considered an instrumental tool of fire exclusion; today, they can play an important role in managing ecosystems.

Green (1977) aptly stated: "Fuelbreak establishment can be a feasible first approach to overall wildland fuel management. But establishment of conventional fuelbreaks has never been considered as the ultimate answer, nor as the only fuel modification practice to be employed. For example, a fuelbreak system to aid in control of wildfires can serve equally well as established control lines for prescribed burning on intervening areas. Periodic burning of adjacent areas, for habitat improvement or fuel reduction, can gradually widen the fuelbreaks and greatly increase their effectiveness for control of wildfires."

Well-designed fuelbreak networks improve options for managing the vegetation mosaic to achieve land management objectives. An entire network of segments may not be justified in all cases, but individual fuelbreak segments may provide protection for high valued resources (e.g., urban dwellings, seed orchards, or plantations). Alternatively, in some locations markets for biomass removal products may cover construction and maintenance costs.

Fuelbreaks may also be appropriate where it is neither feasible nor desirable to treat every stand or landscape unit due to competing objectives. Weatherspoon and Skinner (1995) indicate that adjacent stand damage affects the damage within the plantations—potentially an important consideration for placing fuelbreaks over a landscape.

Management Practices

The impact of management practices on large fire probability largely depends on the type and areal extent of the management activity. For example, fire severity and damage were high in extensively managed areas, whereas intensively managed forest areas improved fire management options in the Greater Yellowstone Area (Omi and Kalabokidis 1991). Extensive management, whether for livestock grazing, timber harvest, or other objective, will likely create a more variable mosaic and leave fuelbeds more prone to large fire occurrence than areas which are intensively tended or maintained. At the same time, it may be desirable to leave coarse debris, fuel jackpots, and snags in areas managed for ecosystem sustainability, all of which could increase the severity of future wildfire occurrences. On the other hand, the removal of activity fuels from intensively managed areas should reduce large fire probability, but only if fuels are managed from a landscape perspective. Concurrently, landscapes which are intensively managed will likely require less prescribed fire in the long run since less residual biomass will be left following activities.

Fuels managed over an entire landscape are likely to reduce the likelihood of large, damaging wildfires since the mosaic will contain buffered areas, including treated areas and older burns. In short-interval, low-moderate fire regimes, non-treatment of fuels may result in greater risk to highly valued areas (Weatherspoon and Skinner 1995).

Over the long term, fire exclusion has probably had a greater influence than any other single practice (excepting perhaps grazing), especially in short return interval fire regimes. Drought impacts interact with management practices (e.g., may limit fire potential in ungrazed areas due to lower biomass, while increasing flammability in forested areas due to restricted moisture levels).

SUMMARY AND CONCLUSIONS

One of the biggest challenges facing land managers in the future will be to design landscapes that balance societal needs with fire regimes characteristic of an area. In some instances, this will require a distribution of fuel profiles which retard (or at least do not promote) wildfire spread and severity across the landscape. In other cases, the challenge will be to manage fuels so as to promote the periodic recurrence of fires historically characteristic of the landscape mosaic (i.e., frequent, low intensity surface fires in long-needled pine communities). These are not mutually exclusive situations, since promotion of periodic fires should eventually result in regulation of the pattern of future wildfires. However, difficulties will persist during the transition to the fire-regulated forest. The fuel management techniques evaluated in this study will be important tools for the land manager to consider in making this transition.

Can fuel modification significantly reduce large fire probability? Our study has found definite reductions in fire hazard accruing to the three alternatives considered (i.e., actual treatments, management practices, and fuelbreaks), but elements of randomness are involved with each treatment. These elements of randomness involve the risk and uncertainty associated with the timing and location of ignitions, subsequent burning patterns, and placement of treatments relative to fire spread pattern.

Actual fuel treatments can reduce fire potential on specific sites. Management practices have the greatest potential for reducing large fire probability, especially when carried out for entire landscapes. Fuelbreaks may provide a useful transition from site-specific projects to management of large areas by breaking individual landscapes into more manageable units.

Actual fuel treatments may be quite effective in reducing fuel hazards in specific stands, yet may provide little security in terms of managing an entire landscape. The effectiveness of actual fuel treatments may be greatest in selected high-valued or high priority areas for fire protection, e.g., urban-interface. Discrete projects also provide a good starting point for treating a large management area. However, these discrete treatments may be too small or too fragmented to significantly reduce large fire probability over a large area or region.

Prescribed fire can be a cost-effective fuel treatment for both small and large areas, but can involve substantial tradeoffs in terms of escape risk and air quality. Further, concerns have been raised about prescribed fire application on a landscape scale, especially regarding the potential impacts of increased smoke. These include effects on human health and concerns about global ecosystems due to increased CO_2 in the atmosphere.

Management practices provide perhaps the greatest potential for reducing large fire probability so long as these are consistent with the historic fire regime in an area. Practices such as fire restoration or timber management should be carried out so that fuels are managed on specific sites, but also in adjoining areas. Thus fires which burn into and from such areas can be more effectively managed.

Fuelbreaks may provide security for specific high-value resources. They also can delineate boundaries and provide anchor points for laying out future landscape management blocks.

Fuels modification can be thought of as representing a continuum of treatment options. From treatments of individual sites to implementing broad policy, we change fuel profiles whenever we manage vegetation. The returns from treatments likewise range over a continuum, from the site-specific project affecting a small area to changes in fire regime resulting from fuel hazard reduction over several watersheds. The spectrum of fuel treatments considered in this study cover the range of alternatives available to land managers. Actual fuel treatments (such as thinning with slash disposal, with or without fire) are appropriate for managing high-value areas (e.g., developments). Management practices (such as grazing, timber harvest, or ecosystem management) provide options over entire landscapes. Fuelbreaks provide permanent installations that may also be important in transitioning from treatment of individual stands to managing entire landscapes.

No single treatment is a panacea or will work in all situations, but each can be important if carried out in concert with a systematic plan. In most landscapes a combination of treatment types will likely be called for, rather than relying on one single treatment over an entire landscape. Each treatment needs to be considered and evaluated on the basis of clear, specific, measurable objectives consistent with sustainability. For example, prescribed fire may not be a useful treatment for an entire landscape, except in park and wilderness areas where the intent is to restore or sustain ecosystem processes.

Fire exclusion during the 20th century probably has had more impact on the landscape than any other single management practice. Undoing impacts of this policy will require the greatest commitment of resources, first to undo any negative impacts (e.g., fuel accumulation) then to implement long-term management of landscapes. Large fire probability will never be eliminated completely (and probably should not be attempted) so long as large tracts of extensively managed wildland areas persist on public and private lands in the US. Under these circumstances, the placement of eventual fires—where and when they occur—will matter most in terms of eventual consequences. Fuels management will be judged effective if by fortuitous circumstances these eventual fires encounter treated areas and fire impacts are reduced as a result of the treatment.

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