Evaluating Tradeoffs Between Wildfires and Fuel Treatments[1]

Philip N. Omi[2]

Abstract
Wildfires continue to burn in the US despite rising concerns for the costs and losses associated with recurrent fire episodes. Prescribed fire and other fuel treatments have been proposed as potential solutions to US fire problems, though fire hazard reduction through fuels management can be controversial. Evaluating tradeoffs between wildfires and fuel treatments for a geographic area may sound straightforward, especially with a growing body of evidence showing fuel treatment effectiveness in reducing wildfire severity within a stand. However analytical problems in assessing treatment productivity are considerable, and may be compounded by deficiencies in the type of data typically collected by public agencies. Other problems are rooted by the relatively scant information available on treatments applied on a landscape scale. Further, public agency proxies for minimizing wildfire cost and net value changes may not link directly with societal values.

Introduction

The US has experienced episodic wildfire seasons in 1988, 1994, 1996, 2000, 2002, and 2003, with significant fire incidents occurring annually. Over the years, policy makers, scientists, and various publics have labored long and hard to develop different alternatives to these recurrent outbreaks. The usual conclusion reached is that solutions involve a systematic approach to fire management, including a combination of fire prevention, fire suppression, fuels management, ecological restoration, and other activities. Traditionally, fire suppression has received the most focus by far. More recently, fuel treatments such as prescribed fire and mechanical thinning are often seen as a critical part of hazard reduction and resource management plans, though tradeoffs between wildfires and fuel treatment alternatives have proven elusive and difficult to establish.

The number and size of fires varies considerably from year to year in the US, with a variety of causative agents (i.e., human activities vs. lightning) and contributory influences, e.g., climate, weather, fuels, topography, and cultural activities. The same variability characterizes fire activities in geographic regions both inside and outside the US, with episodic peaks and followed by lulls in fire activity, with some years near average. Thus, isolating the effects of fuel treatments on future wildfire occurrence, size, and/or effects presents numerous analytical difficulties.

Purpose

Recent US initiatives call for dramatic increases in fuel modification in the nation's forests. However, little information is available for assessing the success of fuel treatments, such as prescribed fire, in reducing wildfire cost and damages. The

---

[1] An abbreviated version of this paper was presented at the second symposium on fire economics, policy, and planning: a global view, 19–22 April 2004, Córdoba, Spain.

[2] Professor, Colorado State University, Department of Forest, Rangeland, and Watershed Stewardship, 131 Forestry, Fort Collins, CO 80523-1472, USA.

purpose of this paper is to examine information currently available from accessible public sources and ascertain their usefulness, if any, for establishing tradeoffs between wildfires and fuel treatments. A case example comparing wildfire and prescribed fire unit costs ($/ha) is presented, using available information from reliable worldwide web sources. A case is then made for considering the plausibility that, at least in the short-term, wildfires may reduce fuels over a much larger area than can be achieved through planned fuel treatments. Longer-term implications also are discussed.

Background

The literature on fuel treatment effectiveness is quite limited (Martinson and Omi, in review). However, to date most studies stop short of evaluating tradeoffs between wildfires and treatments, due to analytical difficulties first identified by investigators such as Davis (1965) and Simard (1976). These and other investigators identify the difficulties associated with establishing the productivity of fuel treatments in terms of effecting subsequent reductions in wildfire costs and losses. Analytically, a major problem lies in determining a production function for fuel treatments. Other difficulties lie in determining rates of technical substitution between various treatment alternatives, or production possibilities for wildfire protection in the urban interface versus ecological restoration of more remote wildland ecosystems. Further, data typically are neither collected nor reported in formats that allow inferences about the relative returns from different types of treatments.

For example, the US federal government only recently has started posting summaries of annual frequency and wildfire area burned, agency wildfire suppression costs, areas treated by prescribed fire, and agency prescribed fire expenditures (i.e., see http: www.nifc.gov/stats). With the exception of area burned, the length of record is quite short for these summaries. However, more critically, there appears to be no way to connect prescribed fire (or any other treatments) to eventual alterations in area burned.

Fuel treatments in advance of wildfires have a long and controversial history in the US, dating back to the so-called “light burning controversy” of the early 20th century. At that time a loose coalition of scientists and timber companies in northern California proposed that periodic surface burning of forests with low intensity fires could reduce the potential for catastrophic wildfires. Although eventually discredited by agency scientists, proponents for light burning periodically questioned the wisdom of agency fire exclusion policies throughout the 20th century and to this day. Only recently have fuel treatments such as prescribed fire and mechanical thinning become mainstream forestry activities, spurred mostly by the recognition of the futility of fire exclusionary policies promulgated by agencies for most of the past 100 years.

Fuels management involves the deliberate manipulation (reduction, removal, and/or rearrangement) of flammable biomass to achieve fire protection and land management objectives (Omi, in prep.). Methods include a variety of mechanical thinning and prescribed fire alternatives, but also include biological, chemical, and natural controls.

Fuel treatments generally manipulate the structure of forests to reduce fire hazards at stand and landscape scales. Structural changes occur in the fuel loadings, horizontal and vertical continuity, age class distributions, and species composition that characterize ecosystems, for example. As a result, wildfire severity is reduced, suppression costs and effectiveness are optimized, and firefighter safety is improved.

Recent proposals for expanding fuel treatments include an interagency strategies for treating 161 million hectares at risk from wildland fires (Williams 2003) and the 2003 Healthy Forests Restoration Act (P.L. 108-148), signed by President G.W. Bush. These initiatives will increase dramatically the magnitude of future areas treated in the US, primarily in the western US.

Federal agency land bases

To visualize some of the analytical difficulties, we will start with a simplified example comparing wildfire suppression and prescribed fire costs on federal lands within the US. Table 1 provides a context for making this comparison by comparing respective land bases managed by the different federal land management agencies.

Table 1— *Differences in federal agency, land bases, and primary management units help explain some, but not all, variability in annual outlays for fire and fuels management.*

Federal agency	Land base, in million ha	Primary management units
USDA Forest Service	77.3	155 national forests and 20 national grasslands
USDI Bureau of Land Management	109.3	Multiple use areas within 50 states
USDI National Park Service	32.4	166 national parks, monuments, preserves, and seashores
USDI Fish and Wildlife Service	38.5	540 National wildlife refuges and thousands of small wetlands and special management areas.
USDI Bureau of Indian Affairs	22.7	Tribal and Indian Trust lands

US federal agencies protect and manage vastly different pieces of real estate, and costs would be expected to vary substantially across timbered national forests of the USDA Forest Service, as compared to the predominant shrublands of the BLM, scenic vistas in national parks and monuments, wetlands in wildlife refuges, or traditional native uses on Indian trust lands. In addition to differences in the values protected, fire behavior and effects will vary widely among the various fuel types represented within each agency's jurisdiction. Differences in expenditures may also reflect agency missions and management practices--and the extent to which agencies have come to grips with managing fire problems in the past.

Wildfire area burned and suppression costs on federal lands

US frequency and area burned summaries go back to the early-mid 20th century. By contrast, cost data are difficult to resurrect and analyze. Although most fires remain small and result in relatively insignificant impacts, occasionally fires grow large and cause significant damages, including loss of life. In some years, climate and fuel conditions will contribute to numerous large fires regionally. Thus a plot of fire frequency against size shows a high fraction of fires in the small size classes, decreasing proportions of mid-sized fires, and an even smaller ratio of large fires (to the total number of fires), as shown in Holmes and others (2003). The relatively few large fires (say in excess of 1,000 hectares) cause the bulk of natural resource damage and housing losses.

Generally, larger fires are more costly, with so called mega fires accounting for as much as 80-90 percent of annual suppression expenditures. However, as might be expected, area burned at best provides an incomplete proxy for the costs, damages, and ecological impacts of forest fires. Data are not collected routinely on fire damages and ecological impacts, so we can only speculate on the magnitude of these outcomes. However, some of the costs can be monitored relatively easily, although suppression expenditures alone will be a poor reflection of all costs associated with wildfires and their management.

Figure 1 shows US federal wildfire suppression costs over time, in this case for the period 1994-2000. Clearly the USDA Forest Service expends more than other federal agencies combined from year to year, followed by the Bureau of Land Management. These agencies protect more public land than the other federal agencies so we would expect higher total expenditures. However these estimates may be misleading since suppression costs will only reflect spending on large fires—spending prior to a fire for staffing, equipment, or other preparedness measures may not be included. Further, spending by state, local, and private entities will not be reflected.

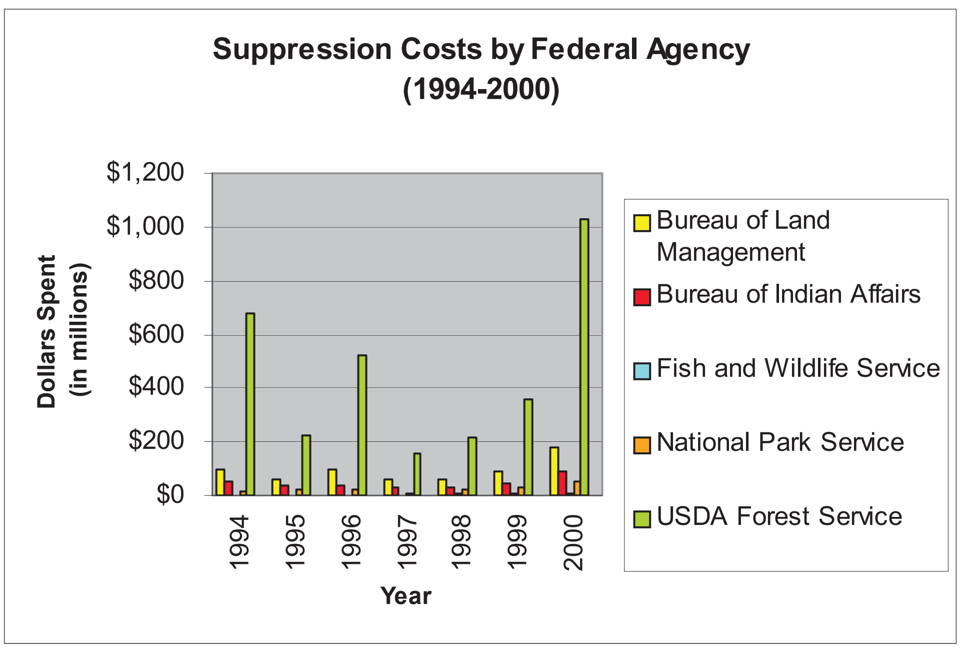

Figure 1— Total suppression expenditures by federal agency, 1994-2000. Estimates are unadjusted by inflation (source: http://www.nifc.gov/stats)

Variation in expenditures can be explained by differences in agency missions, land base, fire loads, and recording standards, as well as numerous other considerations. In this paper I focus on federal agencies, because of their general primacy in US fire and fuels management. Table 1 provides a sense for differences in federal agency mission and land base, but differential fire loads are difficult to assess because a large fire may involve multiple jurisdictions and cross numerous property boundaries as it spreads across a landscape. Typically, expenditures will be assigned to the responsible agency at the location of the fire's origin, but eventually costs may be shared among many other organizations, depending on how the fire spreads and cooperative arrangements among participating entities. Sometimes cost assignments and reimbursements among agencies will require months and even years to resolve, depending on fire complexity and spread patterns. For example, if state and private lands are involved the process could drag on even longer, especially if disaster insurance claims are involved. Thus cost estimates probably need to be viewed with considerable caution.

Table 2 provides an estimate for suppression costs per hectare burned on federal lands during 2000-2002, across all federal agencies in Table 1. Based on area burned, 2000 and 2002 were severe fire years in the US, while 2001 was relatively quiet. During these three years, suppression costs ranged from a low of $375 per hectare in 2001 to $571 per hectare in 2002.

Table 2— *US wildfire burned area and suppression costs can be used to estimate costs per hectare during 2000-2002.*

Year	US wildfire burned area (ha)	US estimated wildfire suppression costs	Estimated costs per ha burned by wildfire	Source
2000	3,409,813	$1.3 billion	$380	http://www.nifc.gov/fireinfo/2000/index.html
2001	1,445,713	$542 million	$375	http://www.nifc.gov/fireinfo/2001/index.html
2002	2,808,738	$1.6 billion	$571	http://www.nifc.gov/fireinfo/2002/index.html

Prescribed fire area burned and costs on federal lands

Information on fuel treatment area and costs is harder to come by than wildfire burned area and costs since agency fuel programs are relatively new and good record-keeping hasn't always been standard practice. In the US, federal agencies have been under increasing pressure to increase usage of prescribed fire and other fuel treatments (such as mechanical thinning), especially after the bad fire years in 2000, 2002, and 2003. Table 3 shows prescribed fire area treated by federal agencies recently. Compared to the agency land bases in Table 1, the annual prescribed fire accomplishment is pretty low considering the total area under each agency's jurisdiction. In fact, the annual area burned by both wild and prescribed fire on federal lands constitutes about one percent or less of total agency land bases.

Table 4 provides estimates for federal agency prescribed fire annual expenditures. As with wildfire costs (Figure 1) the differences between agencies reflects a variety of factors, including type and size of land base, agency mission, workforce expertise and experience, among others. Further, prescribed fire cost estimates reflect expenditures for execution but not necessarily planning, preparation, and data collection costs—or costs associated with escapes, which would show up as wildfire expenditures.

Table 3— *Annual area (ha) treated using prescribed fire by federal agencies during 1995-2000, including 6-year averages and standard deviation (Std). (source: http://www.nifc.gov/stats)*

Agency	1995	1996	1997	1998	1999	2000	Ave (Std)
USDA Forest Service	230,891	249,864	444,396	602,953	558,688	294,833	396,937 (161,546)
Bureau of Indian Affairs	8,502	6,478	14,980	19,549	33,957	1,357	14,137 (11,633)
Bureau of Land Management	22,672	20,243	29,352	81,062	124,696	50,850	54,813 (41,145)
National Park Service	25,101	21,053	28,340	34,869	54,834	7,721	28,653 (15,702)
U.S. Fish and Wildlife Service	84,615	72,874	131,174	115,691	121,663	81,398	101,236 (24,481)
Total	371,781	370,511	648,242	765,006	906,925	436,160	583,104 (225,228)

Table 4— *Federal agency annual prescribed fire expenditures, 1995-1999, unadjusted for inflation (source http://www.nifc.gov/stats). Expenditures will likely increase even more as public agencies commit to expanded prescribed fire programs.*

Year	Bureau of Land Management	Bureau of Indian Affairs	Fish and Wildlife Service	National Park Service	USDA Forest Service
1995	NA	$840,000	NA	$3,200,000	$16,406,000
1996	$1,200,000	$650,000	NA	$3,200,000	$24,500,000
1997	$1,600,000	$800,000	NA	$4,600,000	$29,146,000
1998	$6,700,000	$2,268,000	$4,825,000	$7,000,000	$50,000,000
1999	$10,600,000	$6,300,000	$7,404,000	$9,800,000	$65,000,000

Based on the agency estimates for annual area treated in Table 3 and annual costs (Table 4) for prescribed fire, a rough estimate of agency prescribed fire unit costs (per hectare) can be computed (Table 5). Estimates vary from a low of $41.69/ha for the Fish and Wildlife Service in 1998 to a high of $200.76/ha for the National Park Service in 1998, with an average $96/ha across all agencies during the years of record. Rideout and Omi (1995) have described reasons for the variability in unit cost estimates for prescribed burning, including size of the burn project, objectives, complexity of project, and fuel types. Generally speaking, the larger the prescribed burn project area, the lower the unit costs of treatment execution.

Table 5— *Estimates for prescribed fire costs per hectare, based on agency estimates for costs (Table 3) and area treated (Table 4).*

Year	Bureau of Land Management	Bureau of Indian Affairs	Fish and Wildlife Service	National Park Service	USDA Forest Service
1995	NA	$76.45	NA	$127.48	$71.06
1996	$59.28	$100.36	NA	$152.00	$98.06
1997	$54.51	$53.40	NA	$162.30	$65.58
1998	$82.65	$116.02	$41.69	$200.76	$82.92
1999	$85.02	$185.52	$60.86	$178.73	$116.34

The average prescribed fire unit costs ($96/ha, with a range of $42/ha to $201/ha) can be roughly compared with the average suppression cost ($442/ha) presented in Table 2, ranging from a low of $375/ha in 2001 to $571/ha in 2002. Prescribed fire and fire suppression are not substitutes for one another, so this comparison is not totally meaningful. However, these limited data confirm the conventional wisdom that fire suppression is much more costly than prescribed fire on a unit cost basis.

Discussion

Research has shown that most north American wildlands will eventually burn. Wildfires generally burn with uncontrolled intensity, and attendant high costs and losses. Although significant exceptions occur, e.g., Cerro Grande (2000), prescribed fires generally burn with controllable severities, lower costs, and even produce benefits if applied correctly. So managers (and society) confront a fairly clear choice regarding the type of fire that would be preferred in wild areas, i.e., uncontrollable wildfires vs. managed prescribed fires (or substitute treatments).

The presumed advantage to prescribed fires over other treatment alternatives (such as mechanical thinning) is its low cost. Generally the marginal rate of technical substitution between prescribed fire and thinning would seem to favor prescribed fire except where revenues can be derived from thinning products and/or where smoke and risk of prescribed fire escape are high. A significant exception may occur where the fire treatment confers ecosystem benefits not included in normal calculations, such as nutrient recycling, or fireproofing a stand against future wildfire outbreaks. However the tradeoff between prescribed fire and other treatments, such as mechanical thinning may be less relevant, especially given the analytical difficulties of determining the productivity of each treatment, or substitutability of treatments.

Given the analytical problems associated with evaluating fuel treatment tradeoffs, in the short term we might consider a different tradeoff, that is, between prescribed and wild fires. Prescribed fires not only cost considerably less than wildfires, but recent evidence seems to suggest that wildfires may be far more effective in reducing fuel biomass and landscape flammability than any current fuel treatment alternative. The problem with wildfires is their uncontrollability under extreme burning conditions, although they certainly can be managed under favorable weather conditions or when they run out of fuel.

Wildfires and prescribed fires both consume living and dead biomass, but prescribed fires generally cause less damage to organisms and ecosystems—in fact, depending on burning conditions and objectives, prescribed fires may be beneficial and perhaps required for restoring the health of some ecosystems. The question remains whether enough area can be treated by prescribed fire and other treatments, such as mechanical thinning, to reduce costs and losses by wildfires significantly across the landscape. Though lower in cost than other treatment alternatives, the main problems with prescribed fire are smoke and risk of escape. The main problems with mechanical thinning include high cost and suspicions that it provides a pretext for increased logging on public lands.

In the US we are learning that in order to protect forests and grasslands from fire, we need to use fire, not attempt to exclude it (Williams 2003). In fact, wildfires probably have reduced fuel loads on more areas in recent years than likely could have been achieved by intentional hazard reduction treatments. Since prescribed fires can be used to reduce fuel hazards and the severity of eventual wildfires, society has a fairly clear cut choice to make regarding fire management on public lands—that is, application of fuel treatments such as prescribed fire at relatively low costs versus massive expenditures and damaging wildfires (which coincidentally result in reduced fuel hazards in burned areas), as witnessed every year but especially in bad fire years such as 2000, 2002, and 2003. These years were widely acknowledged as some of the worst to date in terms of costs and losses due to US wildfires, but also they resulted in a great deal of fuel hazard reduction. Arguably, certain sectors of even the worst wildfires also support improved habitat for some wildlife species or improve recreation opportunities.

That wildfires may actually produce benefits may be counter-intuitive and defy current policy mandates, but does have scientific precedent. In particular, fuel consumption theories would suggest that wildfire burned areas, once extinguished, provide important opportunities for managing future fuel hazards and preparing for the next generation of wildfire incidents on the landscape. In fact, a common wildfire control strategy calls for herding fire spread toward or into recently burned areas, where lower fuel levels may result in a more controllable incident.

Moreover, the pattern of recent severe fire seasons and recurrent large incidents suggest that extreme wildfires defy most management efforts, especially in the midst of prolonged droughts. So rather than expending enormous sums of money in fruitless attempts to suppress mega-fires that defy control efforts, perhaps it is time to consider a more nuanced approach toward fire suppression. Such an approach could reduce useless financial commitments that often accompany large fire suppression efforts that are mostly controlled by weather changes—and moreover acknowledge the role that wildfire burned areas can play in the strategic management of landscapes.

The restoration of fire-adapted ecosystems is a growing area of interest in the US, especially when perceived as a plausible solution to the catastrophic wildfires of the late 20th and early 21st centuries. Accordingly, scientists and managers suggest that ecosystems can and should be restored structurally to resemble forests and wildlands prior to European settlement in north America, i.e., with sustainable levels of surface fuels, reduced ladder fuels, few large trees, and relatively open canopies. A forest thus restored should be less prone to devastating crown fires but also able to withstand periodic surface fires. The rationale behind its appeal relies on a combination of scientific studies (mostly dating of historic fire-scars using tree rings and temporally-paired photographs) and informed speculation about the structure (size distribution and species composition) of forests prior to European settlement times. The scientific studies indicate the unequivocal disparity between the low numbers of contemporary ignitions versus the historic higher frequencies of lightning and native firings (most often indistinguishable from each other). Journals of early explorers, news articles, and oral histories reinforce the findings from photo comparisons, suggesting that many of today's forests are choked with dense thickets of small-diameter, shade-tolerant trees compared to yesteryear's open, park-like stands. Devastating wildfire episodes only reinforce the comparisons and emphasize the need for forest restoration.

Over the long-term, forests that are restored ecologically will offer many advantages over the current situation, including safety, aesthetics, and reduced fire hazards. Further, a restored forest is preferable to the devastated aftermath that usually accompanies today's wildfires.

Treatments spread across numerous landscapes over many years may be needed in order to reduce the severity of fuel hazards across the US. As public agencies embark on expanded fuel management programs, an interested public will want assurance that treatments are progressing in accordance with an overall plan for fuel hazard reduction, including treatment of high priority areas. Urban interface and long-needled forests characterized by non-lethal understory fire regimes (Brown 2000) are often cited as high initial priorities, as they should be.

At the same time, agencies will need to develop comprehensive plans that reduce the overall risk of wildfire across the landscape. Annual area (hectares) treated by mechanical and/or prescribed fire may inaccurately represent the accomplishments achieved, especially if treatments are occurring in low-hazard areas mostly easily manipulated or if multiple treatments over several years will be required to reduce wildfire hazards (GAO 2003). Thus current reporting standards (annual area treated and costs) may provide misleading information regarding actual accomplishments. Further, improved reporting of current baselines and annual progress may be required.

Conclusions

Fuel treatments can reduce wildfire severity, but overall effects on landscapes are poorly understood. Evaluation of tradeoffs among treatments is confounded by analytical difficulties associated with understanding fuel management production functions, but also by current reporting practices.

For the foreseeable future, wildfires will continue to burn, sometimes with excessive damages, even as fuel treatment programs are expanded by recent government initiatives. Overall, these damages will recur although the wildfires themselves will in effect reduce fuel hazards within the burn perimeter. Unacceptable wildfire costs and losses will continue until such time as urban interface development can be managed and wildland ecosystems are restored to survive both wild and prescribed fires.

The US experience is coming around to the idea that healthy, resilient forests (that are safe for wild and prescribed fires) are important for protecting people and private property in wildland areas. Firefighting will always be needed in certain areas, such as the urban interface; but in other areas, e.g., historic low severity fire regimes, complete fire exclusion has created unanticipated and unmanageable fuel conditions. Unless fuels are managed in these areas, future fires may become even costlier and deadlier.

Acknowledgements

The study reported here relied on support from the Joint Fire Science Program, USDA Southern Forest Experiment Station, and McIntire-Stennis Cooperative Forestry Program. Jermiah Sisneros provided assistance with graphics.

Literature Cited

Brown, J.K. 2000. Chapter 1: Introduction and fire regimes. Pp 1-6 *In*: Brown, J.K. and J.K. Smith (eds.) 2000. Wildland fire in ecosystems. Effects of fire on flora. USDA Forest Serv. Gen. Tech. Rep. RMRS-GTR-42, vol. 2, 257 p.

GAO. 2003. Wildland fire management. Additional actions required to better identify and prioritize lands needing fuels reduction. United States General Accounting Office. Report GAO-03-805. 67 p.

Davis, L.S. 1965. The economics of wildfire protection with emphasis on fuel break systems. Calif. Div. For., Sacramento. 166 p.

Rideout, D.B. and P.N. Omi. 1995. Estimating the cost of fuels treatment. For. Sci. 41:664-674.

Simard, A.J. 1976. Wildland fire management: the economics of policy alternatives. Can. For. Serv. Tech. Rep. 15. For. Fire Res. Instit., Ottawa, Ont. 52 p.

Williams, J. 2003. Values, tradeoffs, and context: A call for a public lands policy debate on the management of fire-dependent ecosystems.