QUANTIFYING THE POTENTIAL IMPACTS OF FUEL TREATMENTS ON WILDFIRE SUPPRESSION COSTS



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This article is a condensed and slightly edited version of a previously published article appearing in the Journal of Forestry (Thompson et al. 2013). Readers wishing for more detail on study motivation, relevant literature, data sources, modeling methods, and the full presentation of results are encouraged to refer to the article in its entirety, which is available from the author or through the journal.

Introduction

odeling the impacts and effects of hazardous fuel reduction treatments is a pressing issue within the wildfire management community. Prospective evaluation of fuel treatments allows for comparison of alternative treatment strategies in terms of socioeconomic and ecological impacts and facilitates analysis of tradeoffs across land management objectives (Stockmann et al. 2010). While much attention has been focused on assessing how fuel treatments affect expected loss to highly valued resources and assets (e.g., Ager et al. 2007), some have also suggested benefits from fuel treatments in terms of avoided suppression costs (Snider et al. 2006). In this paper, we demonstrate a methodology for estimating potential reductions in wildfire suppression costs. Our approach pairs wildfire simulation outputs with a regression cost model and quantifies the influence of fuel treatments on distributions of wildfire sizes and suppression costs. Estimates of suppression cost reductions can ultimately be compared to treatment costs within a cost-benefit framework.

Motivation for this study stems from four important sources. First, escalating Forest Service wildfire management costs have resulted and may continue to result in reduced budgets and potentially disruptive within-season borrowing to nonfire programs, challenging the ability of the agency to meet societal needs and maintain forest health (Thompson et al. 2013). Second, suppression costs are known to be positively and highly correlated with fire sizes and area burned (Liang et al. 2008, Calkin et al. 2005). Third, modeling efforts

and post-fire analyses suggest that fuel treatments can significantly affect fire spread and final fire size (Cochrane et al. 2012, Collins et al. 2011, Hudak et al. 2011, Ager et al. 2010, Finney 2007). Lastly, fuel treatments can also lead to reductions in final fire size by providing opportunities for enhanced suppression (Hudak et al. 2011, Syphard et al. 2011, Graham et al. 2009, Moghaddas and Craggs 2007).

Methods

Framework

The evaluation of potential cost impacts involves first modeling how treatments will impact fire behavior, and, in turn, modeling how altered fire behavior may impact suppression costs. Figure 1 provides a conceptual framework detailing how the biophysical and socioeconomic context, treatment objectives, and treatment impacts relate to our modeling approach. The likelihood, extent, and intensity of fire, along with the density and spatial pattern of values-at-risk, jointly influence treatment strategies and design objectives (Calkin et al. 2011). In some contexts, this may entail creating areas of low fire intensity and hazard, and fire sizes might actually increase as part of

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Figure 1.—*Conceptual framework for evaluating potential cost impacts of fuel treatments (our approach is highlighted in gray).*

restoring historical fire regimes. In other contexts, treatment strategies are oriented more towards resource protection and the inhibition of fire growth across the landscape.

Multiple mechanisms exist by which fuel treatments could affect suppression costs. Reduced intensity will in many contexts lead to reductions in burn severity (Wimberly et al. 2009, Martinson and Omi 2008), enabling opportunities for resource benefit and moderated suppression responses. These changes in wildfire management could in turn lead to suppression cost reductions. However, Gebert and Black (2012) recently found that less aggressive protection strategies may ultimately lead to costs on par with or higher than more aggressive strategies, owing to longer durations and increased acreages burned.

Another mechanism is to change fire size distributions, which, to reiterate, are a major determinant of suppression costs. Here we focus

on fire size as a primary variable affecting suppression cost estimates (figure 1). The foundation of our approach is the coupling of two peer-reviewed models used by the Forest Service and other Federal land management agencies: (1) FSim (Finney et al. 2011), a spatially explicit large fire (defined at 300 acres or more) occurrence, spread, and containment model and (2) a large-fire cost model (Gebert et al. 2007). The use of a fire growth simulation model approach allows us to directly model disruptions in fire spread and subsequent impacts to fire size. In our approach, therefore, all else being equal, treatments resulting in reduced fire spread will tend to decrease fire size, in turn reducing fire cost.

Fuel Treatment Cost Impact Modeling

Simulating the occurrence and growth of wildfires across the current and hypothetically treated landscapes enables evaluation of changes in fire behavior and, therefore, treatment impacts. Fire size potential is jointly driven by the spatial continuity of fuels and temporal opportunities for spread. To compare simulation results with and without fuel treatments. we set up FSim runs to use identical ignition locations and weather conditions for both scenarios. Thus, weather conditions are controlled for, and changes to modeled final fire size are attributed to, treatment effects (although there is some stochasticity introduced via spotting). Differences in estimated suppression costs (a function of changed fire sizes) reflect expected suppression cost differences due to treatment.

The basic steps of the overall analysis procedure are outlined below. Data needs include an up-to-date map of landscape fuels, spatially delineated fuel treatments, and projected fuel conditions after treatment.

- 1. Obtain or create up-to-date fuels data to represent existing conditions.
- 2. Obtain historical fire occurrence data and identify appropriate RAWS (Remote Automated Weather Station) for fire weather data.
- 3. Design and spatially lay out prospective fuel treatments.
- 4. Modify existing conditions fuels data to reflect fuel treatments.
- 5. Generate FSim wildfire simulation model outputs with and without fuel treatments.
- 6. Aggregate and feed variables output from FSim into the regression cost model to estimate the expected suppression cost for each simulated fire.
- 7. Compare expected suppression costs with and without fuel treatments, across fires, and across simulated fire seasons.

Case Study: Deschutes Collaborative Forest Project

The Deschutes Skyline Project, commonly referred to as the Deschutes Collaborative Forest Project (DCFP), was one of the first 10 projects approved and funded under the Collaborative Forest Landscape Restoration Program and was selected as a pilot study for modeling the impacts of fuel treatments on expected suppression costs. Figure 2 provides a map of the analysis landscape (516,962 acres), as well as the DCFP project area, most of which is located within the Deschutes National Forest (145,000 acres total, 112,000



Figure 2.—*Map of Deschutes Collaborative Forest Project (Collaborative Forest Landscape Restoration Program) study area, with project areas and treatment units highlighted.*

acres of which are National Forest System land), in west-central Oregon. Also identified in figure 2 are the boundaries of seven areas organized for purposes of National Environmental Policy Act analyses, as well as the locations of all ongoing or proposed fuel treatments within the DCFP.

Deschutes National Forest staff provided data on vegetation and fuel layers reflecting existing conditions (EC), as well as treatment polygons and post-treatment (PT) fuel conditions. In total, 66,808 acres (about 46 percent of the DCFP landscape) are projected to receive treatment during the planning period from 2010 to 2019. For modeling purposes, we used a single landscape to reflect the entire suite of fuel treatments. That is, the post-treatment modeling results represent the cumulative effect of all treatments upon completion of implementation. We set up FSim to simulate fire occurrence and growth for a total of 10,000 simulated fire seasons and included a buffer around the study area of width ranging from 2 to 3 miles to account for offsite ignitions that could burn into the study area. To generate weather files for FSim, we used the Colgate RAWS with data from 1990 to 2010 and fire history information for all fires on the Deschutes National Forest over the same period.

Because of the large spatial extent of the treatments and the combination of mechanical treatments with surface and activity fuel treatment, we hypothesized that reductions in fire sizes and expected suppression costs would occur within the study area. We further hypothesized that treatment effects would be more prominent for those ignitions occurring closer to treated areas. Therefore, we present modeling **Table 1**—Percentage reductions to fire size, cost per acre, and cost per fire resulting from treatment, across all large fires igniting within three overlapping landscape areas of increasing size (within treated areas, within a 2-mile buffer of treated areas, and across the entire study area).¹

	Treated areas	2-mile buffer	Entire study area							
	percent change									
Size										
Mean	17.08	11.30	4.68							
Median	22.24	14.97	5.55							
Min	0.66	0.66	0.74							
25th percentile	12.12	5.97	2.78							
75th percentile	23.13	13.20	7.06							
Max	12.84	3.78	0.58							
Cost per acre										
Mean	-2.24	-0.60	0.53							
Median	0.26	0.28	1.00							
Min	-6.73	-0.43	-0.17							
25th percentile	-0.30	1.40	1.22							
75th percentile	-3.18	-1.04	0.35							
Max	-1.74	0.00	0.00							
Cost per fire										
Mean	15.86	10.78	6.71							
Median	17.58	10.63	5.21							
Min	-0.48	0.25	-0.78							
25th percentile	18.60	11.30	5.05							
75th percentile	20.57	12.91	7.04							
Max	5.64	1.06	2.72							

¹Treatment effects dampen as the area increases, owing to the increasing proportion of fires that do not interact with treatments.

results for fires that ignited within three overlapping analysis areas of increasing size (within treated areas, within a 2-mile buffer of treated areas, and across the entire study area).

Results Fuel Treatment Effects on Burn Probability, Fire Size, and Suppression Cost

Table 1 presents summary statistics regarding percentage reductions in fire size, cost per acre, and cost per fire resulting from treatment. With respect to size, reductions are most prominent within treated areas, although off-site effects are discernible. Within treated areas, the mean and median fire sizes decrease by 17.08 percent and 22.24 percent, respectively. Within the 2-mile buffer, mean and median fire sizes decrease by 11.30 percent and 14.97 percent, respectively. Treatment effects dampen as the analysis area increases because of the increasing proportion of fires that do not interact with treatments.

Table 1 also indicates increasing cost per acre with decreasing fire size, consistent with both the cost regression model and historical Deschutes data, where smaller fires tend to cost more per acre. Overall per-fire costs decrease, however, because the effects of the reductions in fire sizes overwhelm the effects of increases in per-acre costs. Reductions in cost per fire also lessen as the analysis area increases and are generally comparable in magnitude to reductions in fire size. Within treated areas, the mean and median fire costs decrease by 15.86 percent and 17.58 percent, respectively, and within the 2-mile buffer mean and median fire sizes decrease by 10.78 percent and 10.63 percent, respectively.

Table 2.—*Mean annual area burned and suppression costs across all 10,000 simulated fire seasons, across fires igniting within three overlapping landscape areas of increasing size (within treated areas, within a 2-mile buffer of treated areas, and across the entire study area).*

	Treated areas		2-mile buffer			Entire study area			
	EC	PT	Reduction	EC	PT	Reduction	EC	PT	Reduction
Area burned	1,315 ac	838 ac	36.25%	2,494 ac	1,911 ac	23.37%	5,398 ac	4,799 ac	11.08%
Suppression cost	\$1,610,806	\$1,042,147	35.30%	\$2,848,653	\$2,195,551	22.93%	\$5,093,335	\$4,432,626	12.97%

EC = *Existing conditions. PT* = *Post-treatment landscapes.*

Annual Area Burned and Annual Suppression Costs

Beyond per-fire results, it is important to aggregate individual simulated fire results into unique fire seasons on an annualized basis. This approach captures both those fire seasons in which no large fires occur and those fire seasons in which multiple large fires occur. Across the entire study area there were approximately 160 fewer large fires after treatment, which reflects the effect of fuel treatments on limiting the growth of ignitions to below the 300-acre "large fire" threshold.

Table 2 presents results for annual area burned and annual suppression costs across all 10,000 simulated seasons. The 25th, 50th (median), and 75th percentiles are not presented as they are all equal to zero—this is because the chance of experiencing a large wildfire in any given year is only about 35 percent (for the entire study area)—so there are many years in which no suppression costs are incurred (within the study area, not the entire Deschutes National Forest). The annual area burned and suppression costs increase as the size of the analysis area increases, simply because more fires are included in the sample. Percentage reductions, however, decrease because a smaller fraction of fires interact with treatments. For fires igniting within treated areas, mean annual

area burned and suppression costs drop by 36.25 percent and 35.30 percent, respectively, after treatment.

Discussion and Concluding Remarks

Our analysis demonstrates that planned fuel treatments within the DCFP study area are likely to reduce the number of large fires, fire sizes, and large-fire suppression costs. In a broader sense, our analysis demonstrates a possible method for estimating the impacts of fuel treatments on financial risk. The tools and approaches defined here could inform treatment design and strategy development across land management agencies interested in better managing suppression costs.

There are caveats, assumptions, and limitations to address regarding this work, and therefore, results of this demonstration should be viewed through a critical lens. First, nearly 50 percent of the DCFP project area will receive treatment; impacts to fire sizes and costs may be dampened on landscapes receiving less treatment. Second, results are dependent on the wildfire simulation and regression cost models used, which come with errors and uncertainties, and which at present do not account for the possibility of changed suppression strategies or tactics. Third, changes in wildfire outputs are

largely driven by projected changes in fire behavior fuel models. Future applications should focus on careful model calibration and validation (Scott et al. 2012, Stratton 2009), in particular the accuracy of projected fuel conditions before and after fuel treatments. Fourth, the only certain way to reduce suppression expenditures is to make a decision to spend less money. and strong sociopolitical pressures or other factors may encourage aggressive suppression independent of potential changes to fire behavior from fuels treatments. Fifth, at present, the modeling technique addresses cost impacts only from changes to final fire size, not fire intensity. Modeling the cost impacts of reduced fire intensity or severity may require alternative fire modeling approaches or the incorporation of local expertise and professional judgment coupled with scenario analysis.

In summary, we believe we have identified a novel and unique methodology that should inform fuel treatment design and implementation, and that ultimately will facilitate the reduction of wildfire management costs. Despite identified limitations, modeling results can provide useful information about the relative magnitude and direction of change resulting from strategic fuels management. Recommended applications include fuel treatment design where impacting fire sizes and suppression costs are explicit management objectives, and analyses of projects moving forward under the Collaborative Forest Landscape Restoration Program and the National Cohesive Wildland Fire Strategy.

References

- Ager, A.A.; Finney, M.A.; Kerns, B.K.; Maffei, H. 2007. Modeling wildfire risk to northern spotted owl (*Strix occidentalis caurina*) habitat in central Oregon, USA. Forest Ecology and Management. 246(1): 45–56.
- Ager, A.A.; Vaillant, N.M.; Finney, M.A. 2010. A comparison of landscape fuel treatment strategies to mitigate wildland fire risk in the urban interface and preserve old forest structure. Forest Ecology and Management. 259(8): 1556–1570.
- Calkin, D.; Ager, A.A.; Thompson, M.P. 2011. A comparative risk assessment framework for wildland fire management: the 2010 cohesive strategy science report. Gen. Tech. Rep. RMRS-GTR-262. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 63 p.
- Calkin, D.E.; Gebert, K.M.; Jones, G.J.; Neilson, R.P. 2005. Forest Service large fire area burned and suppression expenditure trends, 1970–2002. Journal of Forestry. 103(4): 179–183.
- Cochrane, M.A.; Moran, C.J.; Wimberly, M.C.; Baer, A.D.; Finney, M.A.;
 Beckendorf, K.L.; Eidenshink, J.; Zhu, Z. 2012. Estimation of wildfire size and risk changes due to fuel treatments. International Journal of Wildland Fire. 21(4): 357–367.
- Collins, B.M.; Stephens, S.L.; Roller, G.B.; Battles, J.J. 2011. Simulating fire and forest dynamics for a landscape fuel treatment project in the Sierra Nevada. Forest Science. 57(2): 77–88.
- Finney, M.A. 2007. A computational method for optimising fuel treatment locations. International Journal of Wildland Fire. 16(6): 702–711.
- Finney, M.A.; McHugh, C.W.; Stratton, R.D.; Riley, K.L. 2011. A simulation of probabilistic wildfire risk components for the continental United States. Stochastic Environmental Research and Risk Assessment. 25(7): 973–1000.

- Gebert, K.M.; Black, A.E. 2012. Effect of suppression strategies on Federal wildland fire expenditures. Journal of Forestry. 110(2): 65–73.
- Gebert, K.M.; Calkin, D.E.; Yoder, J. 2007. Estimating suppression expenditures for individual large wildland fires. Western Journal of Applied Forestry. 22(3): 188–196.
- Graham, R.T.; Jain, T.B.; Loseke, M. 2009. Fuel treatments, fire suppression, and their interactions with wildfire and its effects: the Warm Lake experience during the Cascade Complex of wildfires in central Idaho, 2007. Gen. Tech. Rep. RMRS-GTR-229. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 36 p.
- Hudak, Andrew T.; Rickert, Ian; Morgan, Penelope; Strand, Eva; Lewis, Sarah A.; Robichaud, Peter R.; Hoffman, Chad; Holden, Zachary A. 2011. Review of fuel treatment effectiveness in forests and rangelands and a case study from the 2007 megafires in central Idaho, USA. Gen. Tech. Rep. RMRS-GTR-252. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 60 p.
- Liang, J.; Calkin, D.E.; Gebert, K.M.; Venn, T.J.; Silverstein, R.P. 2008. Factors influencing large wildland fire suppression expenditures. International Journal of Wildland Fire. 17(5): 650–659.
- Martinson, E.J.; Omi, P.N. 2008. Assessing mitigation of wildfire severity by fuel treatments—an example from the Coastal Plain of Mississippi. International Journal of Wildland Fire. 17(3): 415–420.
- Moghaddas, J.J.; Craggs, L. 2007. A fuel treatment reduces fire severity and increases suppression efficiency in a mixed conifer forest. International Journal of Wildland Fire. 16(6): 673–678.

- Scott, J.; Helmbrecht, D.; Thompson, M.P.; Calkin, D.E.; Marcille, K. 2012. Probabilistic assessment of wildfire hazard and municipal watershed exposure. Natural Hazards. 64(1): 707–728.
- Snider, G.; Daugherty, P.J.; Wood, D. 2006. The irrationality of continued fire suppression: an avoided cost analysis of fire hazard reduction treatments versus no treatment. Journal of Forestry. 104(8): 431–437.
- Stockmann, K.D.; Hyde, K.D.; Jones, J.G.; Loeffler, D.R.; Silverstein, R.P. 2010. Integrating fuel treatment into ecosystem management: a proposed project planning process. International Journal of Wildland Fire. 19(6): 725–736.
- Stratton, R.D. 2009. Guidebook on LANDFIRE fuels data acquisition, critique, modification, maintenance, and model calibration. Gen. Tech. Rep. RMRS-GTR-220. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 54 p.
- Syphard, A.D.; Keeley, J.E.; Brennan, T.J. 2011. Factors affecting fuel break effectiveness in the control of large fires on the Los Padres National Forest, California. International Journal of Wildland Fire. 20(6): 764–775.
- Thompson, M.P.; Calkin, D.E.; Finney, M.A.; Gebert, K.M.; Hand, M.S. 2013. A risk-based approach to wildland fire budgetary planning. Forest Science. 59(1): 63–77.
- Thompson, M.P.; Vaillant, N.M.; Haas, J.R.; Gebert, K.M.; Stockmann, K.D. 2013. Quantifying the potential impacts of fuel treatments on wildfire suppression costs. Journal of Forestry. 111(1): 49–58.
- Wimberly, M.C.; Cochrane, M.A.; Baer, A.D.; Pabst, K. 2009. Assessing fuel treatment effectiveness using satellite imagery and spatial statistics. Ecological Applications. 19(6): 1377–1384. ■

Did You Know

For the 2013 fire season, the Forest Service provided a specific Wildland Fire Web site. The site contained information on a variety of subjects associated with the agency's involvement in wildfire suppression, research, firefighters' roles, and a host of other items.