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An Analytical Approach for Assessing Cost-Effectiveness of Landscape Prescribed Fires[1]

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Abstract
Analytical tools are needed for assessing the cost and effectiveness of large-scale prescribed fire programs. Cost and effectiveness trade-offs for LLS. Department of Interior (USDI) fuels treatment programs were analyzed, with particular emphasis on National Park Service (NPS) hazard fuel reduction projects. A prototype simulation model was developed for the Mineral King study area in Sequoia-Kings Canyon National Parks (SEKI), California. Our prototype process used the FARSITE™ simulator to examine fire size and intensity (with and without fuel treatment) to develop a cost-effectiveness frontier. Managers can use this frontier to select the nrost effective fuel treatment strategy subject to the available budget. Other trade-offs can be examined by transforming simulator outputs (e.g., fuel treatment expenses versus suppression cost savings).

Hazardous fuels have built up on many U.S. Department of Interior (USDI) lands as a result of cultural and ecological processes. Although USDI bureaus (National Park Service, Bureau of Land Management [BLM], Fish and Wildlife Service, and Bureau of Indian Affairs) have reduced fuels through prescribed burning and mechanical manipulation for many years, data are still lacking relating treatment prescriptions to reductions in wildfire risks and hazards. Agencies also lack the ability to identify the most cost-effective fuel treatment for a given budget.

Our project has focused on development of a cost-effectiveness analysis (CEA) system for USDI hazard fuels reduction programs (Omi and others 1998). Analysis tools are needed that will enable the USDI to model the effectiveness of incremental increases to hazard fuel reduction funding in terms of protecting resources at risk, reducing wildfire suppression costs, and restoring natural ecosystems.

Assessing the cost-effectiveness of fuel treatments presents many challenges. These challenges are accentuated when the fuel treatment under consideration is prescribed fire, especially when proposed fires will be applied over a large geographic area such as a watershed. Anecdotal evidence may point to prescribed fire as the fuel treatment of choice for an area, especially in areas managed for ecosystem sustainability or restoration of natural patterns and processes. However, analytical tools are needed for

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justifying the appropriate level of fire application for an area. Although prescribed fire treatments generally are lower in cost than other fuel treatments (i.e., mechanical thinning, fire also is more variable in its effects; Omi and Kalabokidis 1998). This variability in treatment effect is especially evident (and often desired) in the spatial mosaic created by large-scale fire applications. Further, mechanical methods may not be suitable where land management objectives call for restoring or imitating natural patterns and processes over the landscape, such as in a national park.

This paper summarizes initial efforts aimed at constructing a prototype cost effectiveness simulator for the Mineral King study area in Sequoia-Kings Canyon National Parks (SEKI), California.

Methods

Initially we hoped to rely on the existing USDI 1202 database of historical fires to obtain cost and effectiveness estimates. We had hoped that historical evidence would confirm that prescribed fire had reduced wildfire frequency and management costs. When the data proved to be of questionable quality, we relied on a survey of fire managers to provide estimates for fuel load reductions made possible by prescribed fire treatments. These estimates were used to construct custom fuel models representing

Table 1 – *Summary of treatment combinations and outcomes for the Mineral King study area, Sequoia-Kings Canyon National Park.*[1]

Treatment	Area treated (ha)	Treatment cost ($)	Reduction in area burned (ha)	Cost difference ($)
1	2,348	$16,008	1,196	$31,704
1,2	2,810	$16,934	1,264	$33,283
1,2,3	3,781	$18,400	1,849	$58,507
1,2,3,4	4,105	$18,860	2,092	$62,059
1,2,4	3,134	$17,145	1,628	$46,560
2	462	$9,929	391	$7,967
2,3	1,433	$13,877	940	$24,337
2,4	785	$11,621	813	$21,889
2,3,4	1,757	$14,713	988	$25,283
3	972	$12,360	603	$13,383
3,4	1,296	$13,472	600	$12,140
1,3	3,320	$17,712	1,846	$54,082
1,3,4	3,644	$18,270	1,859	$54,015
4	324	$8,952	396	$9,096
1,4	2,672	$16,632	1,658	$48,199

[1]Estimates based on FARSITE™ simulations with and without fuel treatment, and cost estimates from Omi and others (1992, 1995).

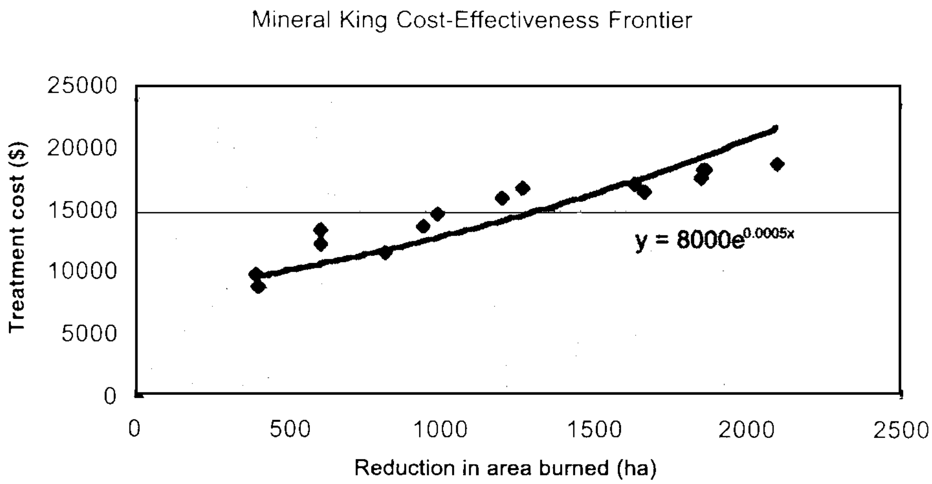

Figure 1.
Cost-effectiveness frontier for large-scale prescribed fire treatments, Mineral King watershed, Sequoia-Kings Canyon National Park, based on FARSITE™ simulations. with and without fuel treatment.

fuelbeds after treatment for running the FARSITE™ model[4] (Finney 1998).

For the prototype simulation four wildfires were ignited on an untreated landscape and allowed to burn for 12 hours. Fuel treatment levels were simulated by considering the different statistical combinations of four segments or zones that could be treated in the potential path of wildfires in the Mineral King watershed (i.e., a total of 15 potential treatment levels and one control or untreated level). To simulate fire spread after treatment, the four wildfires were re-ignited in the same locations and allowed to burn for the same time periods. Fire behavior outputs from all runs were saved in column-delimited format for export into a spreadsheet file. Fire behavior outputs compared included fireline intensity and size.

Acres burned by wildfires after treatment were subtracted from acres burned before treatment, yielding acres reduced. Historical costs for BLM suppressed fires (Omi and others 1995) were used to determine the costs of wildfires. RXCOST (Omi and others 1992) was used to determine cost of the treatments. Prescribed fire costs for treating fuel segments plus subsequent wildfire costs were added together and compared to the wildfire cost without any treatment. Cost and effectiveness tradeoffs between different levels of fuel treatments were assessed graphically.

Results

The simulation results from the 15 treatment combinations were summarized, including reductions in area burned and (treatment plus suppression) cost savings, with and without treatment ***(table 1)***. Simulated burned area reductions ranged from 391 to 2,092 ha with approximated cost reductions from about $8,000 to $62,000.

Results were analyzed graphically ***(fig. 1)***. The ”cost-effectiveness frontier” identifies the trace of greatest reductions in burned area per dollar spent in fuel treatment. In this example one point on this

[4]Mention of trade names or product is for information only and does not imply endorsement by the U.S. Department of Agriculture.

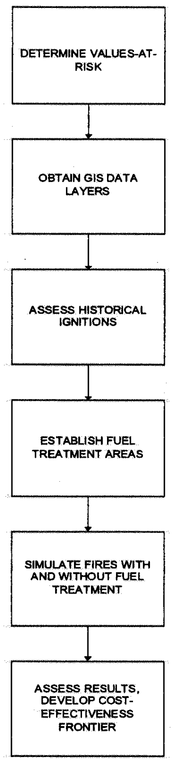

Figure 2.
Flow chart for prototype cost-effectiveness simulator.

path involves treatment of segment 4 with a cost of $8,952 and burned area reduction of 396 ha ***(table 1)***. Alternatively, a manager could treat segments 2 and 4 for a cost of $11,621 and realize a burned area reduction of 813 ha; or he/she could treat segments 1 and 4 for a cost of $16,632 and burned area reduction of 1,658 ha. The most expensive alternative, treatment of all segments (1-4), would cost

$18,860 and reduce burned area by 2,092 ha. Treatment levels interior to the frontier are less cost-effective.

Further, with a limited budget the most cost-effective treatment combination will be that which lies on the frontier and fits within the funding constraint. In this example, if the decision-maker had a fuel treatment budget of $12,000, the best treatment combination would be segments 2 and 4. With a $19,000 budget, the most cost-effective decision would be to treat all four segments. Thus, the choice of treatment alternative is left to the manager, and the cost-effectiveness frontier with the budgetary constraint identifies the best choice.

Treatment and suppression cost savings with the different alternatives were identified ***(table 1)***. These can be graphed and analyzed similarly, along with other outputs from the simulation, e.g., reductions in fire intensity.

Discussion

Construction of the prototype yielded considerable insight into problems associated with simulating cost-effectiveness in the Mineral King study area. Although the prototype was restricted to four fires burning into four treated segments, we were able to demonstrate the feasibility of the process.

Results from the FARSITE™ runs indicate that it is possible to establish a cost-effectiveness frontier for a fuels treatment program involving large-scale prescribed fires. Inferences derived from considering fire area are more reliable than intensity data, but problems with intensity measurements will be addressed in the second phase of this project. Other prescribed fire outcomes that should also be considered include smoke emissions, effects on nonmarket resource, and probability of escape. A more comprehensive framework for evaluating a prescribed fire program can be designed *(fig. 2).* Precise estimates for values-at-risk incorporated in a geographic information system (GIS) may not be needed for our analysis if we identify their spatial location. Further, our work on this prototype suggests that fuel treatments can be analyzed relative to other meaningful indicators (e.g., suppression cost savings, changes in smoke emissions, or any other outcome where estimates are available with and without fuel treatment).

Conclusions

The first phase of this project has assessed problems and established the feasibility of carrying out a cost-effectiveness analysis of hazard fuel reduction programs. The project addressed general issues related to conducting a cost- effectiveness analysis, limitations of available databases, and restrictions resulting-from incomplete understanding of fire behavior, especially large-scale landscape fires. The feasibility of conducting a cost-effectiveness analysis was addressed through the development of a prototype simulator, based on the FARSITE™ simulator with and without fuel treatments proposed for the Mineral King study area. The Mineral King study provides a good test for the prototype because of its fire history, fuel profiles, and ongoing experimentation with large- scale prescribed fires. The prototype's greatest applicability will be to assess areas with aggressive fuel treatment programs, such as Mineral King. However, the methods developed during this project may have broader applicability if analysis units maintain good records on historic fires and fuel treatments. Continued improvement in GIS-based inventories will also rehne our prototype's capabilities.

Acknowledgments

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