Modeling Fuel Treatment Costs on Forest Service Lands in the Western United States

David Calkin *and* **Krista Gebert,** *USDA Forest Service, Rocky Mountain Research Station, Missoula, MT 59801.*

ABSTRACT: *Years of successful fire suppression have led to high fuel loads on the nation's forests, and steps are being taken by the nation's land management agencies to reduce these fuel loads. However, to achieve desired outcomes in a fiscally responsible manner, the cost and effectiveness in reducing losses due to wildland fire of different fuel treatments in different forest settings must be understood. Currently, prioritizing fuel treatment activities and planning budget expenditures is limited by a lack of accurate cost data. The primary objective of this research was to develop regression models that may be used to estimate the cost of hazardous fuel reduction treatments based on USDA Forest Service Region, biophysical setting, treatment type, and design. A survey instrument was used to obtain activity-specific information directly from fire management officers at Forest Service Ranger Districts for treatments occurring between 2001 and 2003. For both prescribed burns and mechanical activities, treatment size described the largest amount of variation in cost per acre, with increased size reducing cost per acre, on average. We confirmed that data on Forest Service fuel treatment activities maintained in the National Fire Plan Operations and Reporting System were not sufficiently accurate for reasonable cost analysis and modeling. West. J. Appl. For. 21(4):217–221.*

Key Words: Fuel treatments, prescribed burning, economics.

There is an increased interest in the economics of fuel reduction treatments as land managers attempt to deal with the high fuel loads resulting from years of successful fire suppression. The primary purpose of the Healthy Forest Restoration Act of 2003 (Public Law 108-148) is: "to reduce wildfire risk to communities, municipal water supplies, and other at-risk Federal land through a collaborative process of planning, prioritizing, and implementing hazardous fuel reduction projects." Therefore, the USDA Forest Service and the Department of Interior (DOI) have committed to a significant increase in hazardous fuel treatments. To achieve desired outcomes in a fiscally responsible manner, the cost and effectiveness of different fuel treatments in different forest settings must be understood. Prioritizing fuel treatment activities and planning budget expenditures is currently limited by a lack of accurate cost data. Existing Forest Service costs estimates are non-activity-specific regional averages and lack the required detail for site-specific or even broad-scale policy analyses. Measuring the effectiveness of fuel treatments in terms of reducing resource loss due to wildland fire requires localized spatial analysis and is beyond the scope of this study. However, accurate cost data are required to develop effective treatment schedules under limited budgets.

Efforts to estimate cost equations for fuel treatments on Forest Service lands have been hampered by limited and often inaccurate cost accounting. Currently, most fuel managers develop budgets for individual fuel treatment activities based on recent costs of similar treatments and personal experience. Ranger Districts typically spend their full fuel treatment budget; however, the budget assigned to a particular activity may not represent what was spent on that activity because resources are often shared among different activities. This issue is further complicated by the fact that the Forest Service accounting system maintains expenditure data for all fuel reduction activities aggregated at the District or even Forest level, making retrieval of individual activity cost data within these systems difficult, if not impossible.

Two fuel treatment databases have emerged in recent years that provide some information on fuel treatment activities—the multiagency National Fire Plan Operations and Reporting System (NFPORS) and the Fuel Analysis, Smoke Tracking Report Access Computer System (FASTRACS) for fuel treatments in the Pacific Northwest. However, the accuracy of their reported cost data is in question and not all biophysical variables that

NOTE: David Calkin can be reached at (406) 542-4151; Fax: (406) 543-2663; decalkin@fs.fed.us. Krista Gebert can be reached at (406) 542-4174; kgebert@fs.fed.us. We thank Tom Preston for research support.

may affect costs are currently maintained in these systems. The NFPORS database lists only planned costs. The FASTRACS database lists both planned and actual costs; however, these fields are typically identical, and it appears likely that actual cost estimates are simply reentries of planned costs.

The 10-year comprehensive strategy to reduce wildland fire risk states as a primary goal to "ensure communities most at risk in the wildland-urban interface receive priority for hazardous fuels treatment" (USDA Forest Service 2001). Additionally, the strategy identifies the need for fuel treatments both in the wildland-urban interface (WUI) and high priority lands identified outside the WUI in condition class 2 and 3. Treatments within the WUI have been shown to be more expensive than wildland treatments due to increased safety and aesthetic concerns (Berry and Hesseln 2004). To increase the scope and effectiveness of fuel treatments on Forest Service lands, more complex treatments under more difficult conditions may be required that may, therefore, increase unit and program costs. Cost estimates generated in this study could help to identify factors that may increase costs above past averages. Accurate cost equations could help managers plan future projects and help develop more accurate budgets.

Previous research into the economics of fuel reduction treatments on Forest Service lands has been limited by the quality of data (both costs and characteristics of the treatments). Berry and Hesseln (2004) estimated cost equations for prescribed burns and mechanical treatments using the Region 6 FASTRACS database, showing that treating fuels within the WUI significantly increases both prescribed burn and mechanical treatment costs. The authors recognized that the quality of their results may be influenced by the quality of the cost data within FASTRACS database. Hesseln (2000) provides an extensive literature review of the economics of prescribed burning, concluding with recommendations for future economics research. González-Cabán (1997) examined managerial and institutional factors to predict differences in per-acre prescribed burning costs for three regions of the Forest Service, showing that institutional constraints significantly affected estimated prescribed burn costs. Cleaves et al. (1999) surveyed fuel managers within the Forest Service to determine factors that influence the cost of prescribed burning activities. Survey participants were asked to rank the importance of selected resource targets and cost influences. Unit size, labor availability, escape fire safeguards, and environmental restrictions were listed as the most important factors influencing treatment cost. Rideout and Omi (1995) developed a cost estimation procedure for ecosystem management projects and hazardous fuels reduction activities using United States Department of the Interior National Park Service data confirming the appropriateness of a constant elasticity of treatment size model and finding that fuel type and treatment method significantly affected costs.

The primary objective of this research was to develop regression models that may be used to estimate the cost of hazardous fuel reduction treatments based on Forest Service Region, biophysical setting, treatment type, and design. By contacting the managers directly responsible for the fuel treatment activities included within the survey, we were able to obtain cost data on treatments that have been conducted since the inception of the National Fire Plan.

Methods

Knowledgeable fuels specialists in Forest Service Region 1 were contacted in the fall of 2002 to determine data availability and specific issues of interest relative to fuel treatment activities. From these discussions, a survey instrument was developed, and a sampling frame based on Region and treatment activity type was developed. The survey instrument and process was further refined through conversations with Forest Service Regional fuels specialists. Activities conducted under the National Fire Plan between 2001 and 2003 listed in the NFPORS database were sampled for western Forest Service lands excluding Alaska (Regions 1–6).

The NFPORS database does not identify the Ranger District where the reported fuel treatment activity was conducted. To obtain this information, we used a GIS overlay of Forest Service Ranger Districts with points identified as the latitude and longitude of the treatment location listed within NFPORS. This led to a substantial number of treatments that did not land within identified Ranger District boundaries. Treatments identified with Ranger Districts were randomly selected based on the proportion of treatments in the NFPORS database by Forest Service Region, treatment type, and whether or not the treatment occurred within the WUI. A total of 265 individual surveys were sent via e-mail to Fire Management Officers (FMOs) at individual Ranger Districts requesting information on 570 prescribed burns and 438 mechanical treatments. Follow-up e-mails and phone calls were made to encourage participation and improve response rates. Due to additional issues associated with the quality of the NFPORS database, many treatments included within the surveys could not be identified by the respondent from the Ranger District where the treatment was reported to have occurred. Due to the challenges of identifying the characteristics of treatments containing data errors in the NFPORS system, no measure of potential sample bias was developed.

Final activity costs, excluding planning costs, were requested for each treatment. Where possible, we requested that costs be assigned to labor charged to the project and donated labor, supplies, equipment, and other direct costs. Although treatment costs from the survey instrument were local estimates of Forest Service expenditures, they are likely a substantial improvement over NFPORS costs, where only project-planned costs were reported. Final treatment size was requested to identify treatments where actual activity size differed from planned treatment size reported within NFPORS. We requested that survey participants confirm the validity of variables of interest that were maintained within NFPORS and requested additional data of interest relating to treatment and site characteristics. Different data of interest were collected for prescribed burn activities and mechanical fuel treatments (see Table 1 for requested data fields for prescribed burns and mechanical treatments).

Because of the highly variable and localized nature of planning costs and our objective of developing cost models that could be applied to proposed treatments in other areas, we chose to exclude planning cost. Additionally, we did not account for management experience and risk profile, which have been shown to influence fuel treatment cost (González-Cabán 1997). These data were not collected because of our desire to develop cost models that could be readily used for management decisionmaking and interpretation of policy implications.

Ordinary least squares regression techniques were used to model cost per acre (CPA) for prescribed burns and mechanical fuel reduction techniques separately. A model of constant elasticity of treatment size was developed and tested that was similar to the models used by Berry and Hesseln (2004) and Rideout and Omi (1995). The functional form of the model was:

Table 1. Variables collected in survey.

Estimated treatment cost ($)
Forest Service Region (1–6)
Was the treatment conducted in the WUI (yes/no)
Activity size (acres)
Fire regime (1–5), Schmidt et al. 2002
Condition class (1–3), Schmidt et al. 2002
Dominant species
Douglas-fir
Lodgepole pine
Chapparal
Ponderosa pine
Pinyon/juniper
Other
Planning document (categorical exclusion, environmental assessment, environmental impact statement)
Activity appealed (yes/no)
Proximity to homes (miles)
Threatened & endangered species present (yes/no)
Fuel load (tons per acre)
Slope (percent)
Aspect (south, southeast, southwest, other)
Elevation (1000 ft)
Distance to work site from Forest Service administrative office (miles)
Activity type
Broadcast burn[a]
Mechanical pile burn[a]
Hand pile burn[a]
Underburn[a]
Hand piling[b]
Biomass reduction[b]
Lop and scatter[b]
Machine pile[b]
Thinning[b]
Ignition method[a]
Drip torch[a]
Aerial[a]
Fuel model (1–13) based on Anderson (1982)[a]
Burn conditions (wet, moderate, dry)[a]
Burn complexity (low, moderate, high)[a]
Activity contracted[b]

[a] Prescribed burns only.
[b] Mechanical treatments only.

$$ln(CPA) = B_0 + B_1 * ln(\text{acres}) + B_i * X \quad (1)$$

where X represents the set of independent variables, including Forest Service region, as well as treatment objective and site attribute variables. We used stepwise regression techniques to identify significant predictor variables. All variables significant at the 0.15 level were included within the regression model. Single-regression models were built for all variables identified within the multiple regression models as significant to test for consistency of the multiple regression coefficients. All costs were adjusted into 2003 dollars.

Results

Activity-specific information was obtained directly from Forest Service Ranger District FMOs and fuel specialists. We received completed surveys from 138 of 265 Ranger Districts (52 percent response rate) that included 297 complete activities (183 prescribed burns and 114 mechanical treatments).

Prescribed Burn Regression Results

Cost data obtained in the survey suggested that planned costs reported in NFPORS do not reflect actual activity costs. For prescribed burns, 44 percent of the sampled activities reported costs per acre that were less than planned costs maintained in NFPORS, 48 percent reported sample costs greater than planned costs, and only 6 percent reported costs equivalent to planned costs. The average absolute difference in CPA reported in this survey and planned costs listed in NFPORS was 66 percent.

The stepwise regression for the prescribed fire data described 59 percent of the variation in CPA (Table 2). The mean predicted value was $60 per acre with a plus or minus 1 SD (68 percent) range of $25 to $143 per acre. The size of the burn explained the largest amount of the variation in CPA, with larger fires costing less on average, with all other variables held constant, than smaller fires. Coefficient interpretation for log transformed variable is that a single 1 percent increase in treatment size results in a B (the estimated coefficient) percent change in the dependent variable (Gujarati 1988). Therefore, increasing treatment size by 1 percent decreased CPA 0.35 percent.

Table 2. Prescribed burn model (R^2 = 0.59; standard error of the estimate = 0.760; sample size = 178).

Variable	B	Standard error	t	Significance
(Constant)	6.290	0.267	23.56	0.000
ln acres	−0.349	0.044	−7.93	0.000
WUI	0.296	0.131	2.27	0.025
Machine pile	−1.252	0.194	−6.46	0.000
Hand pile	−0.431	0.161	−2.68	0.008
Region 2	−0.442	0.223	−1.98	0.049
FM-2	−1.060	0.241	−4.39	0.000
FM-6	−0.859	0.267	−3.22	0.002
FM-11	−0.731	0.176	−4.16	0.000
FM-12	−1.048	0.223	−4.70	0.000
T and E species	0.506	0.146	3.46	0.001
Aerial ignition	−0.562	0.210	−2.68	0.008

FM, fuel model; T, threatened; E, endangered.

For nontransformed variables (all the remaining coefficients in the prescribed burn model are dummy variables), the coefficient interpretation is that the presence of the specified characteristic results in a (exp(B) − 1) * 100% change relative to the reference case. As expected, treatments conducted in the WUI were more expensive than treating non-WUI lands, costing an estimated 34 percent more ({exp(0.296) − 1} * 100%). Machine pile burning and hand pile burning were both less expensive than the baseline, broadcast burn. Region 2 reported significantly lower CPA, whereas cost differences for Regions 1, 3, 4, and 5 did not show a statistically significant difference from the baseline, Region 6. Many fuel model classes showed up as significant predictor variables, with fuel models 2 (grass), 6 (dormant brush), and 11 and 12 (logging slash) reducing CPA compared with the baseline fuel model 9 (closed stands of long needle conifer). Treatments conducted where threatened and endangered species were present were 66 percent more expensive than treating areas without those species present. Burns using aerial ignitions were less expensive, costing on average 57 percent as much as treatments using drip torch ignitions.

These regression results for prescribed burns appear to be comparable with those of Berry and Hesseln (2004) despite differences in the data analyzed. Our results showed that increasing treatment size had a stronger effect on reducing costs, whereas treatments in the WUI did not increase costs as much as in Berry and Hesseln (2004) (34 compared with 43 percent). Additionally, fuel model explains significant variation in our model; however, these data were not collected in the FASTRACS database.

Mechanical Treatment Results

The deviation between CPA reported in this survey and planned CPA in NFPORS for mechanical treatments differed depending on whether the treatment was conducted by the Forest Service or by contractors. For treatments conducted by the Forest Service, 36 percent of the reported activities had a CPA that was less than planned, 52 percent reported a CPA that was greater than planned, 8 percent had equivalent CPAs for reported and planned, and 4 percent did not list planned costs. The absolute average difference between reported and planned CPA equaled 47 percent for Forest Service conducted treatment activities. For contracted activities, 40 percent reported a CPA that was less than planned, 31 percent had reported costs that were greater than planned, 18 percent had equivalent costs, and 11 percent did not list planned costs. Absolute average difference equaled 27 percent for contracted activities.

The regression equation for mechanical treatments described 57 percent of the variation in CPA (Table 3). The mean predicted value was $213 per acre with a plus or minus 1 SD (68 percent) range of $102 to $446 per acre. Similar to the prescribed burn equation, the size of the treatment area explained the largest amount of the variation in CPA, with a 1 percent increase in treatment size reducing costs 0.30 percent. Treatments occurring within the WUI were on average 62 percent more expensive than treatments

Table 3. Mechanical treatment model (R^2 = 0.570; standard error of the estimate = 0.661; sample size = 105).

Variable	B	Standard error	t	Significance
Constant	6.954	0.377	18.422	0.000
ln acres	−0.299	0.057	−5.260	0.000
WUI	0.484	0.160	3.032	0.003
Biomass	1.142	0.279	4.097	0.000
Fuel load (tons per acre)	0.014	0.003	4.636	0.000
Region 3	1.145	0.240	4.766	0.000
FR II	−0.446	0.228	−1.956	0.054
FR III	−0.697	0.177	−3.940	0.000
FR IV	−1.002	0.258	−3.885	0.000
Aspect	0.255	0.149	1.712	0.091
Elevation (1000 ft)	−0.184	0.060	−3.092	0.003

FR, fire regime.

occurring outside the WUI. Biomass activities had higher average CPA than hand pile, the baseline treatment type. CPA increased as fuel loads increased, with a 1.4 percent increase for each additional ton of fuel. Region 3 had significantly higher costs than the baseline, Region 6, whereas Regions 1, 2, and 5 were not significantly different (no mechanical treatments were collected for Region 4). Fire regimes 2 (0–35 years, stand replacing), 3 (35–100 year return interval, mixed severity), and 4 (35–100 years, stand replacing) all had lower average CPA than the baseline fire regime 1 (0–35 years, low severity). CPA decreased as elevation increased, and treatments having a south-facing aspect (including southeast, south, and southwest) increased CPA. Although there was a larger difference between predicted and reported costs for those treatments conducted by the Forest Service compared with contracted treatments, whether a treatment was contracted or not did not significantly affect CPA.

Although model fit is similar to Berry and Hesseln (2004), coefficients for some of the common independent variables between the two studies differ substantially. Similar to the prescribed burn models, our mechanical treatment results indicated that increasing treatment size by 1 percent had a larger influence on reducing costs (0.30 versus 0.11 percent). Additionally, treatments within the WUI had a smaller effect in increasing costs in our model, as compared with that of Berry and Hesseln (2004) (62 versus 356 percent). The increased costs associated with WUI treatments in our mechanical model appear more similar to the additional costs associated with prescribed burning in the WUI.

Discussion

Cleaves et al. (1999) suggested that due to data limitations, the Forest Service needed a uniform, comprehensive system of data collection for prescribed burning activities and costs. This was hardly the first call for improved cost reporting. González-Cabán and McKetta (1986) identified the difficulties associated with fuel treatment cost estimation given the lack of standardized reporting formats. The NFPORS database was designed to assist field personnel in managing and reporting fuel treatment accomplishments.

However, our survey results suggest that the quality of cost data may limit analysis of the factors that affect fuel treatment costs and may ultimately influence the effective implementation of the National Fire Plan and Healthy Forest Restoration Act (HFRA). Results from cost-modeling efforts such as this one could improve data collection within existing databases such as NFPORS and FASTRACS by identifying the importance of obtaining accurate cost data and highlighting those variables that most affect treatment costs. These improvements would provide the necessary data to improve and update cost models and better track fuel treatment performance measures at the regional and national level.

As expected, treating areas within the WUI significantly increased treatment CPA for both prescribed burns and mechanical activities. Identifying these cost differences is important. Legislation such as HFRA directs activities to focus on interface areas, and typical Forest Service fuel treatment budgets require that a set percentage of funding go to treat interface areas. Increasing the level of funding allocated to the interface is likely to result in less area treated for a given budget level. González-Cabán (1997) and González-Cabán and McKetta (1986) suggest managerial factors such as experience, professional fire philosophy, and risk aversion can have a significant influence on fuel treatment costs. Our data collection methodology prohibited detailed review of management influences on costs. Every fuel treatment activity is unique, with different site characteristics, weather, and personnel. The relatively large confidence intervals show that substantial cost differences exist. However, despite the difficulties in measuring management influences and identifying all of the unique characteristics associated with fuel treatments, we were able to identify important treatment and site characteristics that influence unit costs and explain a substantial portion of the variation in treatment costs.

Literature Cited

ANDERSON, H.E. 1982. Aids to determining fuel models for estimating fire behavior. USDA For. Serv. Gen. Tech. Rep. INT-GTR-122. 22 p.

BERRY, A.H., AND H. HESSELN. 2004. The effect of the wildland-urban interface on prescribed burning costs in the Pacific Northwestern United States. J. For. 102(6):33–37.

CLEAVES, D.A., T.K. HAINES, AND J. MARTINEZ. 1999. Prescribed burning costs: Trends and influences in the National Forest System. P. 277–288 *in* Proc. of the symp. on Fire economics planning and policy: Bottom lines, González-Cabán, A., and P.N. Omi (eds). Apr. 5–9, 1999, San Diego, CA. USDA For. Serv. Gen. Tech. Rep. PSW-GTR-173. 332 p.

GONZÁLEZ-CABÁN, A. 1997. Managerial and institutional factors affect prescribed burning costs. For. Sci. 43(4):535–543.

GONZÁLEZ-CABÁN, A., AND C.W. MCKETTA. 1986. Analyzing fuel treatment costs. West. J. Appl. For. 1(4):116–121.

GUJARATI, D.N. 1988. P. 148, 461 *in* Basic econometrics. McGraw Hill, New York. 704 p.

HESSELN, H. 2000. The economics of prescribed burning: A research review. For. Sci. 46(3):322–334.

RIDEOUT, D.B., AND P.N. OMI. 1995. Estimating the cost of fuels treatment. For. Sci. 41(4):664–674.

SCHMIDT, K.M., J.P. MENAKIS, C.C. HARDY, W.J. HANN, AND D.L. BUNNELL. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. USDA For. Serv. Gen. Tech. Rep. RMRS-GTR-87.

USDA FOREST SERVICE. 2001. A collaborative approach for reducing wildland fire risks to communities and the environment: 10-year comprehensive strategy. www.fireplan.gov/reports/11-23-en.pdf; last accessed Dec. 28, 2004.