The Effect of the Wildland-Urban Interface on Prescribed Burning Costs in the Pacific Northwestern United States[1]

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Abstract

The fire suppression policy on American public lands during the last century has resulted in increased fuel loadings, necessitating the use of prescribed fire and mechanical treatments to decrease hazardous fuels and risks of catastrophic wildfire. While these practices are widespread, there is great variability in project costs making planning difficult. Previous studies have examined the factors that influence management costs, yet grapple with the lack of consistent and reliable data. This study uses the FASTRACS (Fuel Analysis, Smoke Tracking, and Report Access Computer System) database from the Pacific Northwest Region of the Forest Service. The database provides information on costs, physical site characteristics, and managerial concerns for fuels management activities from 1993 to the present. Through multiple regression analysis, important influences on fuels management costs were identified. Projects conducted in the wildland-urban interface consistently exhibited higher treatment costs for both prescribed fire and mechanical treatments.

Introduction

In recent years, wildland fire has come to the forefront of public interest. Decades of successful wildfire suppression during the 20th century have resulted in unnaturally elevated levels of burnable wildland fuels that if ignited could lead to catastrophic fires (Arno and Brown 1991). Fuels reduction is of added importance in the wildland urban interface (WUI), where growing populations are making fuels management more complex (Snyder 1999). In populated areas, aesthetics, air quality, structure protection, and risk add new dimensions to management projects. Such complexities may increase costs; however, there is little information available on the relationship between the WUI and costs of management projects.

Cost studies have typically focused on managerial, operational, or physical factors, yet rarely combine all three. Similarly, studies are often focused on either mechanical fuels treatments or prescribed burning. Finally, research across agencies has been difficult given the lack of consistent data. Notwithstanding, Cleaves and others (1999) analyzed trends and influences on prescribed burning costs in the National Forest system during the period from 1985-1994. Similarly, Rideout and Omi (1995) looked at economic data for fuels management on a national level, using

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a National Park Service database. The database included project information, physical site characteristics, and administrative factors. Using a constant elasticity model of declining cost with increases in scale, they found that the costs of fuels treatment varied with respect to the goals of the management efforts. Two general goals were identified in fuels treatment: maintaining or restoring ecosystems and hazard fuel reduction. Higher precision was found in cost estimates for traditional hazard reduction treatments, as compared to ecosystem management treatments. Rideout and Omi also note the lack of available cost data and call for further testing across agencies, fuel treatment purposes, and time.

With respect to fuels treatments in the wildland-urban interface, research is becoming more prevalent albeit complicated. In recent years, there has been increased migration into the rural fringe, (Synder 1999, Davis 1990) giving rise to controversy regarding who is responsible for structure protection (Bakken 1995). While several studies concerning the wildland urban interface have focused on public attitudes and expectations, there are few that examine the effect of the WUI on costs.

The Federal Wildland Policy of 1995 directs federal managers to implement fuels management plans with regard to both ecological and economic principles (USDI/USDA 1995). As funding is allocated, land managers will look towards economic analyses for answers to fuels management questions. While it is apparent that fuels management costs can be highly variable, it has been difficult to identify sources of variation, frequently due to the lack of available data; records are often non-existent or incomplete.

This study seeks to look at costs using a region-wide analysis of USDA Forest Service (FS) and USDI Bureau of Land Management (BLM) fuels management data. We pay particular attention to the influence of the WUI on fuels management costs. We develop two regression equations to study the factors that affect costs for prescribed burning, and for mechanical fuels treatments. It is necessary to derive two equations given the difference in variables collected for each management project. We begin by discussing our methodology and assumptions and regression results, and conclude with a discussion of our findings.

Methodology

The Pacific Northwest Region of the Forest Service and the BLM in Oregon and Washington have been tracking fuels management projects for almost a decade as part of the Fuel Analysis, Smoke Tracking, Report Access Computer System (FASTRACS). This system enables managers to record fuels management project information including costs, physical site characteristics, and managerial factors. In its fullest, unedited form the database contains 18,600 observations with 196 data categories representing years 1993 to 2002, with the bulk of the information from 1999 to 2001. Most of the data are from Forest Service (FS) Ranger Districts and BLM Resource Areas.

For both mechanical and fire analyses, we focused only on the years after the National Fire Plan came into effect; beginning in the fall of 2000. This legislation made more money available to fuels managers for fuels treatment; therefore, it is logical that the cost structure before this legislation would be somewhat different than following it. Overall, only 17% of the fire and mechanical treatments in FASTRACS occurred before or during 2000, with the remaining 83% from 2001 and

2002. A t-test of both databases indicated significant ($p < 0.05$) differences in costs during 2000 vs. in 2001 and 2002. Furthermore, a preliminary study of the mechanical database indicated strong evidence (t-test $p < 0.001$) that costs differed between 2001 and 2002. Therefore, we used only data from 2001 in the analysis of the mechanical treatments. For fire treatments, there was no observable difference between 2001 and 2002 (t-test $p = 0.326$), therefore, records from both years were included. Based on previous studies, data availability, and completeness, we selected variables that have been instrumental in explaining treatment costs. Data include physical site information, managerial and administrative factors, and operational information. For a full listing, see Appendices A and B.

Factors were selected via backwards elimination based on an extra sums of squares F-test. Elimination criteria was $p > 0.100$. For categorical variables such as activity type and season for example, reference levels were tested to assess significance. Levels of categorical variables were either retained or eliminated as a group. To assess the role of the wildland urban interface, a WUI indicator variable was included in analyses of both fire and mechanical treatments. We first fit a rich model with as many independent variables as possible and then worked through the backward elimination process. The resulting equations for mechanical fuels treatments and prescribed burning are depicted by (eq. 1) and (eq. 2),

$$\begin{aligned}\ln CPA &= \beta_0 + \beta_1 WUI + \beta_2 DPA + \beta_3 \ln Acres + \beta_4 Slope + \\ &\beta_5 Winter + \beta_6 Summer + \beta_7 Fall + \beta_8 Handpile + \beta_9 MachinePile \\ &+ \beta_{10} MachineLeave + \beta_{11} Ladder + \beta_{12} Thinning + \beta_{13} PCT + \\ &\beta_{14} FRI + \beta_{15} FRIII + \beta_{16} FRIV + \beta_{17} NaturalFuels + \beta_{18} NFPproject, \qquad [1]\end{aligned}$$

$$\begin{aligned}\ln CPA &= \beta_0 + \beta_1 WUI + \beta_2 DPA + \beta_3 \ln Acres + \beta_4 Slope + \\ &\beta_5 Elevation + \beta_6 Cascade + \beta_7 Broadcast + \beta_8 MachinePile + \beta_9 HandPile \\ &+ \beta_{10} LandingPile + \beta_{11} Defensible + \beta_{12} WUI + \beta_{13} EcoSys + \beta_{14} 4x4 + \\ &\beta_{15} 6x6 + \beta_{16} 8x8 + \beta_{17} HarvOther + \beta_{18} WholeTree + \beta_{19} BrushGrass \\ &+ \beta_{20} DougFir + \beta_{21} Lodge + \beta_{22} Mixed + \beta_{23} FRII + \beta_{24} FRIII + \beta_{25} FRIV \qquad [2]\end{aligned}$$

where, the dependent variable is the natural log transformation of cost. Costs were also adjusted for inflation using the GDP deflator to year 2000. The independent variables are WUI, designated protection area (DPA), the natural log of acres (lnAcres), slope and elevation, season, activity method, fire regime, natural fuels indicator, NFP project, objectives and fuels types.

Results

Results will be presented first for the mechanical treatment model, and then for the prescribed burning model. We will then turn to a general discussion of the results.

Mechanical Fuels Treatments

Factors included in the final regression equation (Equation 1) for costs of mechanical treatments are WUI indicator, designated protection area indicator, lnAcres, average slope, season, activity type, fire regime, natural fuels indicator and National Fire Plan project indicator. Variance inflation factors indicated no collinearity (VIF < 10). Coefficients, t-tests and 95% confidence intervals for each variable are listed in Table 1.

$$\mathrm{lnCPA} = 0.219 + 1.271\mathrm{WUI} + 0.469\mathrm{DPA} - 0.190\mathrm{lnAcres} + 3.203\text{-}2\mathrm{Slope} + 0.988\mathrm{Winter} + 0.943\mathrm{Summer} + 1.293\mathrm{Fall} + 1.447\mathrm{Handpile} + 1.375\mathrm{MachinePile} - 0.125\mathrm{MachineLeave} + 0.774\mathrm{Ladder} - 0.694\mathrm{Thinning} + 1.391\mathrm{PCT} + 1.693\mathrm{FRI} + 1.925\mathrm{FRIII} + 2.061\mathrm{FRIV} + 0.967\mathrm{NaturalFuels} - 0.607\mathrm{NFPproject} \tag{1}$$

The regression accounts for 57.8% (adjusted R-squared 0.578) of the observed variation in the dependent variable, lnCPA, based on 526 observations (Table 1).

Based on the extra sums of squares F-test, the regression variables were strongly significant ($p < 0.02$) with the exception of lnAcres ($p = 0.2889$). The variable lnAcres was retained for practical purposes for cost estimation. The estimated effect of the number of acres after anti-log transformations of both dependent and independent variables indicates that as the number of acres doubles, the cost increases by a factor of 0.927 (95% confidence interval {0.851 to 1.0069}). If the number of acres increases tenfold, the cost increases by a factor of 0.778 (95% confidence interval {0.586 to 1.030}). These economies of scale are also supported in the literature (Rideout and Omi 1995, Jackson and others 1982).

There was very strong evidence (t-test p value < 0.001) that the wildland urban interface indicator variable had an effect on per-acre costs. After anti-log transformation, the estimate of the coefficient for the WUI indicator is 3.56 (95% confidence interval {2.52 to 5.05}) indicating costs are almost four times greater in WUI areas. There was also strong evidence (t-test p value = 0.011) that the designated protection area indicator had an effect on cost per acre. The effect of DPA was 1.60 (95% confidence interval {1.11 to 2.29}), indicating that mechanical activities in protected areas are associated with per acre costs 60% higher than those in non protected areas.

Slope had a small but significant positive effect, signifying that increases in slope are associated with slight increases in per-acre costs. The natural fuels indicator also had a positive effect, suggesting that higher costs are associated with natural fuels as opposed to activity fuels or 'undetermined.' There was a negative effect from the NFP project indicator, which shows that NFP projects tend to have lower costs than non-NFP projects for mechanical treatments.

Three multi-level categorical variables; season, activity type, and fire regime were included in the final regression equation. Reference levels for these variables were spring, 'hand leave,' and fire regime II, respectively, and were not therefore shown in the regression. The coefficients indicate that mechanical activity costs were estimated to be significantly higher in all seasons when compared to spring activities (t-test $p < 0.02$). Furthermore, fire regime II was associated with lower per-acre costs than fire regimes I, III, and IV (t-test $p < 0.001$).

Table 1--Coefficients, t-tests, and 95% confidence intervals for independent variables in the regression model for mechanical treatments from the year 2001.

Mechanical Treatments 2001[a]

	Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	.219	.542		.404	.686	-.846	1.285
ind.WUI	1.271	.177	.270	7.194	.000	.924	1.619
DesignatedProtectionArea	.469	.184	.102	2.553	.011	.108	.830
LNACRES	-.109	.062	-.058	-1.750	.081	-.232	.013
AverageSlope	3.203E-02	.005	.210	5.841	.000	.021	.043
ind.winter	.988	.387	.080	2.557	.011	.229	1.748
ind.summer	.943	.175	.202	5.381	.000	.599	1.288
ind.fall	1.293	.209	.238	6.195	.000	.883	1.704
act.Handpile	1.447	.422	.304	3.426	.001	.617	2.277
act.MachinePile	1.375	.477	.168	2.882	.004	.438	2.312
act.MachineLeave	-.125	.445	-.022	-.280	.780	-.998	.749
act.LadderFuelReduction	.774	.460	.131	1.682	.093	-.130	1.677
act.Thinning	-.694	.482	-.085	-1.439	.151	-1.642	.253
act.PCT	1.391	.611	.100	2.275	.023	.190	2.592
ind.FireRegime1	1.693	.209	.364	8.100	.000	1.282	2.103
ind.FireRegime3	1.925	.284	.289	6.769	.000	1.367	2.484
ind.FireRegime4	2.061	.286	.311	7.202	.000	1.499	2.623
ind.NaturalFuels	.967	.167	.209	5.772	.000	.638	1.296
NFPProject	-.607	.232	-.103	-2.620	.009	-1.062	-.152

a. Dependent Variable: LNCPA R Squared = 0.593 Adjusted R Squared = 0.578 n = 526

Prescribed Burning

Factors included in the final regression equation (Equation 3) for costs of fire treatments are WUI indicator, designated protection area indicator, lnAcres, average slope, midpoint elevation, Cascade slope indicator, activity type, management objectives, harvest specifications, fuels species, and fire regime.

$$\mathrm{lnCPA} = 5.205 + 0.358\mathrm{WUI} + .0300\mathrm{DPA} - 0.178\mathrm{lnAcres} + 3.282\text{-}3\mathrm{Slope} - 1.55\mathrm{Elevation} + 0.517\mathrm{Cascade} - 0.258\mathrm{Broadcast} - 1.503\mathrm{MachinePile} - 1.259\mathrm{HandPile} - 1.652\mathrm{LandingPile} - 0.351\mathrm{Defensible} + 0.205\mathrm{WUI} - 0.300\mathrm{EcoSys} - 0.3174x4 - 0.1206x6 + 0.2518x8 + 0.391\mathrm{HarvOther} - 0.566\mathrm{WholeTree} - 0.173\mathrm{BrushGrass} + 0.306\mathrm{DougFir} + 0.618\mathrm{Lodge} + 0.427\mathrm{Mixed} + 0.427\mathrm{FRII} + 0.268\mathrm{FRIII} + 0.355\mathrm{FRIV} \quad (3)$$

Variance inflation factors indicated no collinearity (VIF < 10). Coefficients, t-tests, and 95% confidence intervals for each variable are listed in Table 2.

The remaining variables were retained given strong statistical significance (extra sums of squares F-test p < 0.04). Factors which were eliminated from the fire equation include season, year, county population, state, natural fuels indicator, pile calculation method, pile tons, pile indicator (y/n), NFP project indicator, load calculation method, agency, work agent, multiple ignition indicator, and ignition method. The final regression equation had an adjusted R-squared of 0.610, based on 837 observations (Table 2).

Table 2--Coefficients, t-tests, and 95% confidence intervals for independent variables in the regression model for fire treatments from the years 2001 & 2002.

Fire Treatments 2001 & 2002[a]

	Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	5.205	.196		26.589	.000	4.821	5.590
ind.WUI	.358	.070	.156	5.101	.000	.220	.496
DesignatedProtectionArea	.300	.065	.130	4.604	.000	.172	.427
LNACRES	-.178	.022	-.227	-7.944	.000	-.222	-.134
AverageSlope	3.282E-03	.002	.050	1.689	.092	-.001	.007
MidpointElevation	-1.55E-04	.000	-.147	-4.383	.000	.000	.000
ind.CascadeSlope	.517	.135	.150	3.816	.000	.251	.782
act.Broadcastburn	-.258	.200	-.036	-1.292	.197	-.651	.134
act.MachinePileBurn	-1.503	.108	-.395	-13.936	.000	-1.714	-1.291
act.HandPileBurn	-1.259	.066	-.546	-19.048	.000	-1.388	-1.129
act.BurnLandingPiles	-1.652	.132	-.358	-12.543	.000	-1.910	-1.393
obj.DefensibleSpace	-.351	.113	-.078	-3.110	.002	-.572	-.129
obj.ForestHealth	-.303	.086	-.103	-3.502	.000	-.472	-.133
obj.WUI	.205	.090	.068	2.265	.024	.027	.382
obj.EcosystemRestoration	-.300	.119	-.074	-2.527	.012	-.533	-.067
HarvSpecs.4X4	-.317	.113	-.078	-2.813	.005	-.538	-.096
HarvSpecs.6X6	-.120	.094	-.034	-1.275	.203	-.304	.065
HarvSpecs.8X8	.251	.167	.039	1.505	.133	-.076	.579
HarvSpecs.other	.391	.092	.114	4.233	.000	.209	.572
HarvSpecs.WholeTreeYard	-.566	.112	-.136	-5.054	.000	-.786	-.346
fuel.BrushGrass	-.173	.174	-.026	-.994	.321	-.516	.169
fuel.DougFirHemlockCedar	.306	.139	.073	2.209	.027	.034	.579
fuel.Lodgepole	.618	.110	.178	5.613	.000	.402	.834
fuel.MixedConifer	.427	.077	.186	5.561	.000	.276	.578
ind.FireRegime2	.467	.109	.102	4.295	.000	.254	.680
ind.FireRegime3	.268	.098	.095	2.727	.007	.075	.461
ind.FireRegime4	.335	.117	.097	2.863	.004	.105	.564

a. Dependent Variable: LNCPA R Squared = 0.622 Adjusted R Squared = 0.610 n = 837

The WUI indicator was again strongly significant (t-test $p < 0.001$) with an estimated coefficient after transformation of 1.430 (95% confidence interval {1.246 to 1.642}), indicating that the per-acre costs for WUI fire treatments are about 43% more than the per-acre costs of non-WUI fire treatments. Additionally, there was strong evidence (t-test $p < 0.001$) to include the designated protection area indicator variable in the regression model for fire treatments. After anti-log transformation, the estimated coefficient for DPA was 1.349 (95% confidence interval {1.188 to 1.533}), indicating that per-acre costs of fire activities in designated protection areas are approximately 35% percent higher than those in non-protected areas.

There was strong evidence (extra sums of squares F-test $p = 0.039$) to include lnAcres in the regression model, and again, the sign of the coefficient indicated economies of scale. Midpoint elevation and average slope both had a small but significant (t-test $p < 0.10$) effect on costs. Estimated effects were such that steeper slopes were associated with slight increases in cost, and higher elevations were associated with slight decreases in cost. The estimated effect of the Cascade slope indicator suggested that per-acre costs of fire treatments are higher on the west side of the Cascade ridge.

Multi-level categorical variables (and reference levels) in the fire regression included activity type (underburn), primary project objective (fuel reduction), harvest specifications (not applicable), fuels species (ponderosa pine), and fire regime (fire regime I). Burning activities in all fire regimes were associated with higher per-acre costs when compared to fire regime I. Where primary project objectives are concerned, activities with the objectives defensible space, forest health, and ecosystem restoration were estimated to have significantly lower costs than those with the objective of fuel reduction (t-test $p < 0.02$). In contrast, activities with the objective 'WUI' were associated with significantly higher costs than those with fuel reduction objectives (t-test $p = 0.024$). All of the burn activity types were estimated to have lower costs than underburning. However, there was only very weak evidence (t-test $p = 0.197$) supporting a difference of costs between broadcast burning and underburning. All of the fuels species were associated with significantly higher costs than ponderosa pine (t-test $p < 0.03$), with the exception of brush/grass, for which there was no evidence of a difference (t-test $p = 0.321$).

Discussion

Despite the large amount of information available in FASTRACS and extensive records, the R-squared values were somewhat lower than have been observed in previous studies (Rideout and Omi 1995, Jackson and others 1982). Lower observed R-squared values may be due to the lack of information regarding key factors. For example, Rideout and Omi (1995) used information on escapes as a variable, and ranking scores on values including ignition complexity, natural resources, historic importance, and wildlife habitat. Additionally, previous studies have focused more specifically on only one or two management objectives, resulting in less cost variability.

It is notable that WUI was a significant factor in both mechanical and fire treatments. Analysis of the FASTRACS data clearly indicates that costs are higher for WUI activities. For mechanical treatments, WUI activity costs were estimated to be more than three times as much as for non-WUI activity costs. For fire treatments, WUI per-acre activity costs were estimated to be 43% higher than those of non-WUI activities. The discrepancy in the size of the effect of WUI on costs between fire and mechanical treatment is somewhat unexpected. It is possible that when WUI fuels treatments are associated with particularly high risk (and high cost), they are more likely to be treated via mechanical activities than via fire activities. Additionally, managers noted that burning costs can be prohibitively high in the WUI, so it may be the case that the data are skewed to include a greater relative number of low-cost WUI fire treatments. DPA was also a significant factor in both the fire and the mechanical analyses, indicating that proximity to population centers or areas of smoke management concern can be associated with elevated fuels treatment costs. These results quantify the role of the wildland urban interface in fuels management costs and suggest that it may be worthwhile to consider WUI and DPA when estimating activity costs.

Activity type and unit size are generally considered to be two important factors influencing treatment costs (Cleaves and Brodie 1990, Cleaves and others 1999). Activity types were found to be significant for both fire and mechanical treatments. Since this is a primary factor considered in budgeting, it is not surprising that different activities were associated with different costs. The variable lnAcres was included in both regression equations and results support the findings of previous studies (Rideout and Omi 1995, Jackson and others 1982) that per-acre costs generally decrease as the number of acres treated increases. For the fire data this observation was strongly significant, but this was not the case for the mechanical data. Because the number of acres treated does not greatly affect the per-acre costs of mechanical treatments, this analysis indicates that other factors are more important for estimating costs. With respect to the number of acres treated, mechanical treatments are more likely to have higher fixed costs and lower variable costs than fire treatments. Therefore, mechanical treatment per-acre costs will be less sensitive to overall treatment scale.

Primary project objectives were significant in the analysis of the fire data, supporting the findings of previous research (Cleaves and Brodie 1990). Furthermore, burning activities with WUI objectives were associated with higher costs than those with fuel reduction objectives. All other primary project objectives were associated with lower costs than those of activities with fuel reduction objectives. This result strengthens the argument that costs associated with WUI fire treatments are higher than those associated with non-WUI treatments. Primary project objectives were not found to be significant in the analysis of the mechanical data. It is possible that the significance of this factor was masked by other significant factors in the mechanical analysis.

Conclusion

The results of this analysis clearly indicate that per-acre costs of fuels treatments are higher in wildland urban interface areas for both mechanical fuels reduction and prescribed burning methods. Additionally, per-acre costs were found to be higher in areas of concern for smoke management or near population centers. Currently, WUI and DPA are not specifically factored into budgeting for fuels management activities in the Pacific Northwest. However, this analysis indicates that considering WUI and DPA could produce more accurate cost estimates. DPA is, of course, only a factor in Oregon where the smoke management plan delineates these areas. It would be possible, however, to develop similar classifications in other states based on smoke management concerns and population densities.

The FASTRACS database has great potential for future studies. It may become a more central part of the management system of the Pacific Northwest region. As more managers use FASTRACS, it will become a more complete record of management activities across the region. Additionally, perhaps it can serve as a model for a nation-wide data management system. It is apparent from discussions with managers that Region 1, in particular, completely lacks any kind of tracking program of fuels management projects and costs. For accurate economic analysis of the FASTRACS database, however, it will be necessary to more precisely define what activity costs are composed of, as well as to define actual vs. planned costs. This will insure that costs may be compared across districts, forests, and regions. Additionally, for future studies of wildland urban interface issues, it will be necessary to develop a working definition of this term.

For statistical analysis purposes, more complete records are needed in the FASTRACS database. For example, many observations in this study were incomplete in the potentially important fields of weather, fuel moisture, condition class, threatened and endangered species, predominant aspect, and position on slope. Furthermore, it may be possible to record information on factors like unit shape, access, distance traveled to worksite, crew composition, hours of labor, days of mop-up, and occurrences of escapes in future editions of FASTRACS. This would enable a more comprehensive analysis, and the ability to predict a greater portion of cost variability. At this point, while FASTRACS is the best source for region-wide information on fuels management projects, there is still a lot of room for improvement.

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Appendix A) Mechanical treatments: Variables and descriptive statistics

Variables	Levels (# of Observations)	n	Min.	Max.	Mean	Standard Deviation
Cost Per Acre (CPA)		840	0.01	2,077.80	176.81	241.37
lnCPA		840	-5.12	7.64	4.23	2.10
Acres Treated		771	1	2,322	89.86	176.74
lnAcres		771	0	7.75	3.66	1.27
Cost Year		840	2001	2001	2001	0
IND.2001		840	1	1	1	0
Season	Winter (24)	768	0	1	0.03	0.17
	Spring (193)	768	0	1	0.25	0.43
	Summer (334)	768	0	1	0.43	0.50
	Fall (217)	768	0	1	0.28	0.45
WUI	(439)	840	0	1	0.52	0.50
DPA	(326)	785	0	1	0.42	0.49
Average Slope (%)		751	0	60	17.10	14.66
Midpoint Elevation (Feet)		743	500	6,450	4442.59	1148.35
Activity Type	Hand pile (274)	840	0	1	0.33	0.47
	Hand Leave (37)	840	0	1	0.04	0.21
	Machine Pile (169)	840	0	1	0.20	0.40
	Machine Leave (142)	840	0	1	0.17	0.38
	Ladder Fuel Reduction (139)	840	0	1	0.17	0.37
	Thinning (61)	840	0	1	0.07	0.26
	PCT (18)	840	0	1	0.02	0.14
Fire Regime	Fire Regime 1 (350)	652	0	1	0.54	0.50
	Fire Regime 2 (109)	652	0	1	0.17	0.37
	Fire Regime 3 (95)	652	0	1	0.15	0.35
	Fire Regime 4 (98)	652	0	1	0.15	0.36
Natural Fuels	(424)	840	0	1	0.50	0.50
County Population		827	2,397	322,959	69,522.15	72,026.73
Cascade Slope	(West = 78)	827	0	1	0.09	0.29
State	(WA = 40)	827	0	1	0.05	0.21
Primary Project Objective	Forest Health (157)	840	0	1	0.19	0.39
	WUI (132)	840	0	1	0.16	0.36
	Ecosystem Restoration (76)	840	0	1	0.09	0.29
	Fuel Reduction (475)	840	0	1	0.57	0.50
NFP Project	(636)	840	0	1	0.76	0.43
BLM	(144)	840	0	1	0.17	0.38
Work Agent	Timber Sale Purchaser (10)	839	0	1	0.01	0.11
	Contractor (552)	839	0	1	0.66	0.47
	Force Account (227)	839	0	1	0.33	0.47
Valid N (listwise)		515				

Appendix B) Fire treatments: Variables and descriptive statistics

Variables	Levels (# of Observations)	n	Min.	Max.	Mean	Standard Deviation
Cost Per Acre (CPA)		1946	0.65	1,426.00	85.24	107.78
lnCPA		1946	-0.43	7.26	3.84	1.21
Acres Treated		1316	0	15,222	101.85	563.91
ln(Acres Treated + 1)		1316	0	9.63	3.07	1.55
Cost Year		1946	2001	2002	2001.49	0.50
Year	2001 (999)	1946	0	1	0.51	0.50
	2002 (947)	1946	0	1	0.49	0.50
Season	Winter (217)	1423	0	1	0.15	0.36
	Spring (289)	1423	0	1	0.20	0.40
	Summer (30)	1423	0	1	0.02	0.14
	Fall (887)	1423	0	1	0.62	0.48
WUI	(826)	1946	0	1	0.42	0.49
DPA	(784)	1879	0	1	0.42	0.49
Average Slope (%)		1769	0	87	19.95	16.89
Midpoint Elevation (ft)		1778	500	6,500	4057.96	1141.87
Activity Type	Broadcast Burn (49)	1946	0	1	0.03	0.16
	Machine Pile Burn (211)	1946	0	1	0.11	0.31
	Hand Pile Burn (811)	1946	0	1	0.42	0.49
	Burn Landing Piles (227)	1946	0	1	0.12	0.32
	Underburn (648)	1946	0	1	0.33	0.47
Fire Regime	Fire Regime 1 (884)	1529	0	1	0.58	0.49
	Fire Regime 2 (152)	1529	0	1	0.10	0.30
	Fire Regime 3 (317)	1529	0	1	0.21	0.41
	Fire Regime 4 (176)	1529	0	1	0.12	0.32
Natural Fuels	(1014)	1946	0	1	0.52	0.50
County Population		1927	1,547	322,959	85,050.01	78,959.44
Cascade Slope	(West = 225)	1927	0	1	0.13	0.34
State	(WA = 247)	1927	0	1	0.13	0.33
Primary Project Objective	Defensible Space (82)	1848	0	1	0.04	0.21
	Forest Health (255)	1848	0	1	0.14	0.34
	WUI (284)	1848	0	1	0.15	0.36
	Ecosystem Restoration (152)	1848	0	1	0.08	0.27
	Fuel Reduction (1075)	1848	0	1	0.58	0.49
NFP Project	(1288)	1946	0	1	0.66	0.47
BLM	(261)	1946	0	1	0.13	0.34
Work Agent	Timber Sale Purchaser (57)	1930	0	1	0.03	0.17
	Contractor (244)	1930	0	1	0.13	0.33
	Force Account (1629)	1930	0	1	0.84	0.36
Fuels Species	Brush/Grass (40)	1404	0	1	0.03	0.17
	D-Fir, Hemlock, Cedar (149)	1404	0	1	0.11	0.31
	Lodgepole (253)	1404	0	1	0.18	0.38
	Ponderosa (328)	1404	0	1	0.23	0.42
	Mixed Conifer (634)	1404	0	1	0.45	0.50

Appendix B, continued

Variables	Levels (# of Observations)	n	Min.	Max.	Mean	Standard Deviation
Harvest Specifications	4"x4' (114)	1787	0	1	0.06	0.24
	6"x6' (134)	1787	0	1	0.07	0.26
	8"x8' (39)	1787	0	1	0.02	0.15
	Other (167)	1787	0	1	0.09	0.29
	Whole Tree Yard (96)	1787	0	1	0.05	0.23
	N/A (1237)	1787	0	1	0.69	0.46
Load Calculation Methods	NA/piled (307)	1711	0	1	0.18	0.38
	Other (445)	1711	0	1	0.26	0.44
	Transect (9)	1711	0	1	0.01	0.07
	Local (714)	1711	0	1	0.42	0.49
	Photo Series (236)	1711	0	1	0.14	0.34
Pile Calculation Methods	Non Pile (681)	1609	0	1	0.42	0.49
	Aerial Survey (5)	1609	0	1	0.00	0.06
	Local Method (294)	1609	0	1	0.18	0.39
	Pile Wizard (288)	1609	0	1	0.18	0.38
	Ocular (344)	1609	0	1	0.21	0.41
Pile Tons		1442	0	3,876.60	76.79	238.43
Pile y/n	(yes = 1249)	1946	0	1	0.64	0.48
Ignition Methods	Aerial (32)	974	0	1	0.03	0.18
	Combination (36)	974	0	1	0.04	0.19
	Hand (906)	974	0	1	0.93	0.25
Multiple Ignitions	(124)	1155	0	1	0.11	0.31
Valid N (listwise)		585				

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