INTEGRATED FUELS TREATMENT ASSESSMENT: ECOLOGICAL, ECONOMIC AND FINANCIAL IMPACTS

FINAL REPORT 99-1-1-05

November 2004

Submitted to Joint Fire Science Program, 3833 S. Development Ave., Boise, Idaho 83705

INTEGRATED FUELS TREATMENT ASSESSMENT: ECOLOGICAL, ECONOMIC AND FINANCIAL IMPACTS

FINAL REPORT

Principle Investigators:

Hayley Hesseln: Associate Professor, Centre for Studies in Agriculture, Law and the Environment, University of Saskatchewan, Saskatoon, SK Canada S7N 5A8. PH: 306.966.8407, FX: 306.966.8413, EM: h.hesseln@usask.ca.

John B. Loomis: Professor, Dept. of Agric. And Resource Economics, Colorado State University, Fort Collins, CO 80523. PH: 970.491.2485, FX:970.491.2067, EM: jloomis@ceres.agsci.colostate.edu.

Douglas B. Rideout: Professor, Forest Sciences, Colorado State University, Fort Collins, CO 80523. PH: 970.491.7234, FX: 970.491.6754, EM: doug@CNR.Colostate.edu

Armando González-Cabán: Economist, USDA Forest Service-PSW Riverside Fire Lab., 4955 Canyon Crest Drive, Riverside, CA 92507-6099. PH: 909.680.1525, FX: 909.680.1501, EM: agc/psw_rfl@fs.fed.us

Contributing Authors:

Alison Berry, M.Sc. Forestry, University of Montana, Missoula, MT

Donald Helmbrecht, National Center for Landscape Fire Analysis, University of Montana, Missoula, MT 59812.

Kenneth Homik, M.Sc. Forestry, University of Montana, Missoula, MT

Andrea Rodriguez, Program Analysis and Statistics, Department of Public Health, 172 W. 3rd St., San Bernardino, CA 92415

Janet Sullivan, Rocky Mountain Research Station, USDA Forest Service, Forest Sciences Lab, Missoula, MT 59807.

ACKNOWLEDGEMENTS

This research wouldn't have been possible without the support of many individuals and agencies. We would like to thank the following people for generously providing data and advice. Thanks to the fuels managers of USDA Forest Service Regions 1, 4, and 6, for taking the time to provide data, and to answer many questions. In particular, we want to express gratitude to Mary Ann Sanford, Tim Rich, and John Orbeton. We also wish to acknowledge the support and insightful comments offered by David Jackson and Krista Gebert. Special thanks to Dennis Dupuis and Andrea Gilham who coordinated the work with the Confederated Salish-Kootenai Tribe and the Blackfeet Tribe. We also want to thank both tribal councils who graciously allowed us to conduct this research on tribal land.

Thanks to the Survey Research Center at California State University, Chico for their performance of the interviews and mailings. The analysis of interview data was supported by the W1133 Regional Research project of the Colorado Agricultural Experiment Station. With respect to the recreation survey, thanks to Dave Payne, Jack Kirkendall, Cynthia Manning, John Turner and John Waverek who assisted with survey sites in Montana; and Gary Biehl, Barbara Bonefeld, Judith Leraas Cook, R. Jeffrey Fernandes, David Levinson, Ed Mathews, Ken Nehoda, Bob Roessler, Howard Roose, Bonnie Von Hoffman who provided data and statistics.

Special thanks to Jimmie Chew, Carol Miller, LLoyd Queen, and the National Center for Landscape Fire Analysis for their comments and support with the ecological modeling project. Finally, thanks to Greg Jones and Kevin Hyde for providing technical support and advice regarding MAGIS.

This work was funded by a grant from the Joint Fire Sciences Program of the USDA Forest Service and the DOI Bureau of Land Management. McIntire Stennis funding also supported portions of this research.

EXECUTIVE SUMMARY

The fire suppression policy on public lands during the last century in the United States has resulted in increased fuel loadings, necessitating the use of prescribed fire and mechanical treatments to decrease hazardous fuels and risks of catastrophic wildfire. The effects of such activities are wide-ranging and of concern to fuels managers, policy-makers and society. This report is a compilation of seven research initiatives relating to fuels management. These include two cost studies; three economic analyses based on contingent valuation and travel cost methodology; a landscape-level analysis of fuels treatment effectiveness; and a synthesis using MAGIS (Multiple-resource Analysis and Geographic Information System) to evaluate decision-making at the landscape level. The results of each of these studies are addressed in turn.

Financial Analysis

We used the FASTRACS (Fuel Analysis, Smoke Tracking, and Report Access Computer System) database from the Pacific Northwest Region of the Forest Service to identify important influences on fuels management costs. We developed two separate regression equations to examine the costs of prescribed burning and mechanical fuels treatments. Our findings suggest that projects conducted in the wildland-urban interface (WUI) consistently exhibited higher treatment costs for both prescribed fire and mechanical fuels treatments. Other significant factors included number of acres treated, designated areas for protection, slope, treatment type, and fire regime. Fuels treatments costs were also associated with elevation, location, primary project objectives harvest specifications, and fuels species.

Turning to prescribed fire in the WUI, we tested the hypothesis that high degrees of complexity reduce both average unit size and average acres burned per year in ponderosa pine forests in the northwestern United States. Six complexity elements were tested; Threats to Boundaries, Fuels/Fire Behavior, Objectives, Social Improvements or Resources to be Protected, Air Quality Values to be Protected, and Political Concerns. We also tested the effect of district population. Results indicate that complexity associated with air quality reduces average unit size and yearly accomplishments. However, the results for the remaining complexity elements were somewhat ambiguous given data variability.

Economic Analysis

Wildfire and prescribed fire have the potential to affect user demand and value for recreation, making such information important to the decision-making process for fire managers. However, such information is not always readily available. We conducted surveys on 22 sites within four National Forests in western Montana to determine fire effects on recreation demand for hiking and biking and net economic benefits to visitors. Net value per trip for hikers was $37. There was no statistical difference for consumer surplus between hiking and biking. Although there were differences in existing visitation between hikers and bikers, there were no statistical differences between the two groups as a result of fire effects. We found that hikers' demand decreased slightly in areas recovering from crown fire and increased in areas recovering from prescribed fire. Bikers' response to both types of fire was the opposite of hikers; for example, bikers showed a slight decrease in annual trips as areas recovered from prescribed fire. Individual value per trip was unaffected by both wild and prescribed fire for both activity groups. Although our recreation demand shifts in response to fire were statistically significant, the magnitude of the predicted changes in demand were not substantial from a managerial perspective suggesting that recreation users in Montana are not affected by fire characteristics resulting from prescribed burns or crown fires. Demand however, decreased by both user groups as area burned increased and the amount of burn viewed from trails increased suggesting that the size and extent of burns do affect visitation.

The second paper in the economics section evaluates the suitability of the contingent valuation method to measure non-market benefits incurred by ethnic groups from a forest fire reduction program using prescribed burning similar to President Bush's Healthy Forest Initiative. There were significant differences in interview response rates of Whites, African Americans and Hispanics (using both English and Spanish language versions). Reasons for refusing to pay higher taxes for the prescribed burning program were not statistically different across the three groups. A likelihood ratio test indicates that the logit willingness to pay regression coefficients are different between Hispanics, Whites and African Americans. However, there is no statistical difference between White and African American logit slope coefficients nor in mean willingness to pay. In separate logit willingness to pay functions for Hispanics taking the survey in English or in Spanish, the bid slope coefficient was insignificant, indicating their responses were insensitive to the dollar amounts they were asked to pay. This is an unusual result for a dichotomous choice contingent valuation survey. Thus, it suggests for Hispanics in California the contingent valuation method, whether conducted in their native Spanish language or in English, may not perform as well as for other ethnic groups. Overall, there is substantial support for forest fuels reduction projects using prescribed burning in California.

Finally, the third paper in the economic section compares survey response rates, protest responses and willingness to pay for two forest fire prevention programs. Respondents were selected from two Native American tribes and general Montana residents. A combination phone interview with respondents followed by a mailed information booklet was used to convey the details of the prescribed burning and mechanical fuels reduction programs. Survey response rates were significantly different between Native Americans and other Montana residents at the 0.05 level for the initial contact phone interview, and at $p = 0.001$ for the follow-up in-depth interview. We also tested for differences between Native Americans and Montana residents' refusals to pay involving rejection of the premise of our CVM (i.e. protests). Protest rates for the prescribed burning program were not statistically different for Native Americans and for Montana residents, but were significantly different at the 0.01 level for the mechanical fuels reduction program Results from bivariate probit with sample selection models indicate that there is no significant difference between the Native American and Montana general populations' willingness to pay for either program.

Ecological Analysis

Fire exclusion has altered fire regimes and the composition and structure of vegetation in many Northern Rocky Mountain ecosystems. These changes in vegetation may increase the risk of losing key ecological components in the event of a wildland fire today. Current fire management policy recognizes these risks and aims to restore the natural role of fire by means of various fuel treatment strategies. The objective of this study was to apply a modeling approach toward analyzing the impacts of fuel treatment strategies from an ecological perspective at the landscape scale. We integrated a condition class ruleset into a spatially explicit simulation model, SIMPPLLE, in order to assign treatment strategies based on the dynamic changes to condition class on a decadal basis. The response of condition class to each of eight, 100-year treatment strategies was compared to the original modeled conditions. Simulation results suggest that treating areas of moderate departure from historical conditions and allowing wildland fire use in wilderness were the most efficient restoration strategies. However, difficulties with integrating different modeling approaches limited comparison between strategies.

Synthesis

We examine the costs of fuels treatments at the landscape level from ecological and economic perspectives. We set up a model using MAGIS (Multiple-resource Analysis and Geographic Information System), to examine landscape changes in response to mechanical treatments and the use of prescribed burning on forested lands including wildland-urban interface areas. Our objectives were to assess treatment types and costs based on changing budget levels and tradeoffs between two objectives: ecosystem restoration and hazard reduction in the wildland urban interface. Specifically, we addressed how budgets affect allocation of fuels management resources between wild lands and the WUI; and cost-effectiveness of treatments across different objectives. Our findings suggest that treatments in the WUI do not generate sufficient revenue to cover the costs of operations. Conversely, management objectives that focused on reducing ecosystem risk resulted in positive present net values. None of the treatments succeeded in reducing condition class three areas to zero. The synthesis is important for technology transfer because it provides a method by which forest managers can use financial, economic and ecological data to evaluate fuels treatment program efficiency.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS III

EXECUTIVE SUMMARY V

Financial Analysis v
Economic Analysis v
Ecological Analysis vi
Synthesis vii

INTRODUCTION 1

FINANCIAL ANALYSIS 3

THE EFFECT OF THE WILDLAND-URBAN INTERFACE ON PRESCRIBED BURNING COSTS IN THE PACIFIC NORTHWESTERN UNITED STATES 5

ALISON BERRY & HAYLEY HESSELN 5
INTRODUCTION 5
METHODOLOGY 6
RESULTS 7
Mechanical Fuels Treatments 7
Prescribed Burning 8
DISCUSSION 9
CONCLUSION 10
LITERATURE CITED 11

THE EFFECT OF COMPLEXITY ON PRESCRIBED FIRE ACCOMPLISHMENTS IN NORTHWESTERN PONDEROSA PINE FORESTS 13

KENNETH HOMIK & HAYLEY HESSELN 13
INTRODUCTION 13
BACKGROUND 14
METHODS 15
Survey Design 15
Survey Methodology 16
RESULTS 17
Hypothesis Testing 21
Air Quality Values 22
Fuels/Fire Behavior 22
Social Values to be Protected 22
Population 22
Program Constraints 23
Cost Factors 25
DISCUSSION 25
CONCLUSION 30
LITERATURE CITED 31

ECONOMIC ANALYSIS 33

THE EFFECTS OF FIRE ON RECREATION DEMAND IN MONTANA 35

HAYLEY HESSELN, JOHN LOOMIS & ARMANDO GONZÁLEZ-CABÁN 35
INTRODUCTION 35
METHODOLOGY 35
Fire Effects TCM 36
Benefit Calculations 37
Hypothesis Tests 37
Data Collection 38

RESULTS 39
CONCLUSION........ 44
LITERATURE CITED 45

A MULTICULTURAL EVALUATION OF THE PERFORMANCE OF CONTINGENT VALUATION FOR FOREST FIRE PREVENTION........ 47

JOHN LOOMIS, ARMANDO GONZÁLEZ-CABÁN & HAYLEY HESSELN........ 47
INTRODUCTION........ 47
HYPOTHESES: RESPONSE RATE & PROTEST RESPONSES........ 49
WTP Model and Related Hypothesis Tests........ 50
SURVEY DESIGN........ 51
Data Collection and Survey Mode........ 51
RESULTS........ 52
Comparison of Survey Response Rates........ 52
CONCLUSIONS........ 56
REFERENCES........ 57

DO NATIVE AMERICANS RESPOND DIFFERENTLY FROM THE GENERAL POPULATION TO THE CONTINGENT VALUATION METHOD? 59

ARMANDO GONZÁLAZ-CABÁN, ANDREA RODRIGUEZ, JOHN LOOMIS & HAYLEY HESSELN 59
INTRODUCTION........ 59
METHODS........ 60
Contingent Valuation Method 60
Dichotomous Choice CVM........ 60
SURVEY DESIGN........ 60
Program Valued........ 60
Focus Groups........ 62
Sample Design........ 62
Survey Mode........ 63
RESULTS AND DISCUSSION........ 63
Analysis of Protest Responses........ 64
Statistical Analysis of WTP Responses 65
Comparison of Willingness to Pay between Native Americans and MT households........ 72
CONCLUSIONS........ 73
REFERENCES........ 73

ECOLOGICAL ANALYSIS........ 77

A MODELING APPROACH TO ANALYZING ECOLOGICAL CONDITION AS A RESULT OF ALTERNATIVE FUELS TREATMENT STRATEGIES........ 79

DONALD HELMBRECHT & HAYLEY HESSELN 79
INTRODUCTION........ 79
METHODS........ 79
Study Area........ 79
RESULTS........ 83
Treatment Strategy Simulation Modeling........ 83
DISCUSSION........ 87
Treatment Strategy Simulation Modeling........ 87
Modeling Pitfalls........ 91
CONCLUSIONS........ 93
REFERENCES........ 93

SYNTHESIS........ 97

AN ECONOMIC ASSESSMENT OF FUELS TREATMENTS AT THE LANDSCAPE LEVEL........ 99

HAYLEY HESSELN & JANET SULLIVAN........ 99
INTRODUCTION........ 99

METHODOLOGY 100
Ecosystems At Risk (EAR) *101*
Communities At Risk (CAR) *102*
Scenarios *102*
RESULTS 103
DISCUSSION 106
REFERENCES 107
APPENDIX A: BITTERROOT FRONT MAP 109
APPENDIX B: TRAVEL COST/CVM RECREATION SURVEY FOR MONTANA 111
APPENDIX C: CVM SURVEY 119

INTRODUCTION

The importance of fuels management has increased in recent years to federal fire managers, scientists, and the public. Forest fuels have reached historically high levels, as has the risk of catastrophic wildfire, threatening to cause increased levels of property, cultural and resource damage. In response to increased fuel loading, federal fire management officers must increasingly employ fuels management techniques to mitigate potentially damaging effects and to restore natural ecosystem processes. Given the need to reduce hazards related to increased fuel loads, it is of critical importance for federal managers and policy makers to collectively evaluate the social, economic and financial tradeoffs among alternative fuels treatment methods to meet efficiency and ecosystem management objectives.

Currently, one of the biggest obstacles to allocating resources efficiently is the lack of information and comprehensive methodology to evaluate the effectiveness of fuels management alternatives and to evaluate the tradeoffs among them. Fuels management may be employed through mechanical, chemical or biological methods, as well as prescribed and wild fire. Each method results in an array of financial expenditures and returns depending upon capital and labor requirements, as well as the physical and environmental factors associated with sites. In addition, each type of treatment has social implications that arise from visual effects, byproducts such as smoke, changes in air quality and aesthetics, and finally, changes in ecosystem function. Without a complex suite of information regarding each of these issues, managers will find it difficult to choose the best-suited fuels management tools and strategies to efficiently achieve financial, ecological and economic objectives.

Our research provides critical information and economic tools to enable federal fire managers to gain a better understanding of the factors related to fuels management alternatives, and to evaluate and compare alternatives based on an extensive analysis of the full effects of such alternatives. This research is very timely as fire managers are increasingly using fuels management alternatives to meet the Federal Wildland Fire Policy objectives, and are required to formulate sound management plans based on science and economic principles. Understanding the investment-return relationships of fuels management alternatives, and the economic and financial costs and benefits resulting from both market and non-market effects, will enable managers to meet objectives such as long-term cost minimization, programming efficiency, and damage reduction, more effectively. We address each of these important issues and provide a comprehensive framework within which to compare and evaluate the long-term tradeoffs among alternative fuels treatments using MAGIS (Multi-resource Analysis and Geographic Information System).

We approached this work with three primary research objectives, results from which were synthesized to develop a comprehensive analysis of fuels treatment alternatives. Our research focused on financial evaluation of expenditures and returns; economic analysis of non-market values arising from public perceptions and recreation use; and finally, an ecological assessment to examine fuels management alternatives based on condition class and departure from historical fire return intervals.

Our research results are summarized in three sections. First, the financial analysis contains the results from a study that examines the costs of a variety of mechanical and prescribed burning fuels treatments for the pacific northwestern United States. Also in this section are the results form a study that examines the effects of increasing complexity on costs. The second section includes results from three studies: a travel cost/contingent valuation approach to examining demand and consumer surplus for hikers and mountain bikers in Montana; a contingent valuation study to examine perceptions and attitudes toward fuels management methods in California and Montana based on language and ethnic differences; and finally the use of contingent valuation to assess Native American values with respect of fuels treatments. The third section looks at the ecological effects of fuels treatments aimed to restore ecosystems to historic conditions based on condition class and departure from mean fire intervals. Finally, we use MAGIS to synthesize our results and examine the effects of fuels management treatments based on minimizing risk in the wildland-urban interface and/or the ecosystem, or maximizing present net value. Our research objectives are restated at the beginning of each section.

FINANCIAL ANALYSIS

This section contains the results of two studies designed to examine the costs of mechanical fuels treatments and prescribed burning. Our primary objective was to examine program costs and to identify factors affecting costs. This information is important to enhance federal managers' abilities to estimate the costs of alternative treatments and to allocate resources more efficiently in the long run. This research will be important to federal agencies engaged in fuels management with hazard reduction and ecosystem enhancement objectives.

THE EFFECT OF THE WILDLAND-URBAN INTERFACE ON PRESCRIBED BURNING COSTS IN THE PACIFIC NORTHWESTERN UNITED STATES

ALISON BERRY & HAYLEY HESSELN

INTRODUCTION

In recent years, wildland fire has come to the forefront of public interest. Decades of successful wildfire suppression during the 20th century have elevated levels of burnable wildland fuels that if ignited could lead to catastrophic wildland fire (Arno and Brown 1991). Fuels reduction is of added importance in the wildland urban interface (WUI), where changing demographics are making fuels management more complex (Snyder 1999). In populated areas, aesthetics, air quality, structure protection, and risk add cost and complexity to management projects; however, there is little information available that defines the relationship between costs of management projects in the WUI and the factors that influence those costs.

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 et al. (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 at a national level, using National Park Service data that 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.

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 WUI have focused on public attitudes and expectations, there are few that examine the effect of the WUI on costs. Furthermore, 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.

The Federal Wildland Fire 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. In this study we look at region-wide fuels management costs for the USDA Forest Service (FS) and USDI Bureau of Land Management (BLM). 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. At the time of our analysis, in its fullest, unedited form the database contained 18,600 observations with 196 data categories representing years 1993 through 2002, with the bulk of the information from 1999 to 2001. Most of the data are from 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. 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.

Factors were selected via backwards elimination based on an extra sums of squares F-test. The elimination criterion 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 backwards elimination process. The resulting equations for mechanical fuels treatments and prescribed burning are depicted by equations [1] and [2],

$$\begin{aligned} \ln CPA = {} & b_0 + b_1 WUI + b_2 DPA + b_3 \ln Acres + b_4 Slope + \\ & b_5 Winter + b_6 Summer + b_7 Fall + b_8 Handpile + b_9 MachinePile \\ & + b_{10} MachineLeave + b_{11} Ladder + b_{12} Thinning + b_{13} PCT + \\ & b_{14} FRI + b_{15} FRIII + b_{16} FRIV + b_{17} NaturalFuels + b_{18} NFPproject \end{aligned} , \quad [1]$$

$$\begin{aligned} \ln CPA = {} & b_0 + b_1 WUI + b_2 DPA + b_3 \ln Acres + b_4 Slope + \\ & b_5 Elevation + b_6 Cascade + b_7 Broadcast + b_8 MachinePile + b_9 HandPile \\ & + b_{10} LandingPile + b_{11} Defensible + b_{12} WUI + b_{13} EcoSys + b_{14} 4x4 + \\ & b_{15} 6x6 + b_{16} 8x8 + b_{17} HarvOther + b_{18} WholeTree + b_{19} BrushGrass \\ & + b_{20} DougFir + b_{21} Lodge + b_{22} Mixed + b_{23} FRII + b_{24} FRIII + b_{25} FRIV \end{aligned} , \quad [2]$$

In both equations, 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, Cascade slope indicator, season, activity method, fire regime, natural fuels indicator, national fire plan project (NFP), objectives and fuels types.

RESULTS

Mechanical Fuels Treatments

The results are significant with an adjusted R-squared value of 0.578 based on 526 observations. The extra sums of squares F-test indicated the regression variables were strongly significant ($p < 0.02$) with the exception of lnAcres ($p = 0.2889$). (Table 1).

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

Variable	Coefficient	P-value
constant	0.219	0.686
WUI	1.271	0.000
DPA	0.469	0.011
lnAcres	-0.109	0.081
slope	0.03203	0.000
winter	0.988	0.011
summer	0.943	0.000
fall	1.293	0.000
hand pile	1.447	0.001
machine pile	1.375	0.004
machine leave	-0.125	0.780
ladder	0.774	0.093
thinning	-0.694	0.151
PCT	1.391	0.023
FR I	1.693	0.000
FR III	1.925	0.000
FR IV	2.061	0.000
natural fuels	0.967	0.000
NFP	-0.607	0.009
Dependent Variable: lnCPA		
R-squared 0.593		
Adjusted R-squared 0.578		
N = 526		

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 et al. 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 designated protection area 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 $p < 0.001$).

Prescribed Burning

Factors included in the final regression equation were 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. Coefficients, t-tests, and 95% confidence intervals for each variable are listed in 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.

Variable	Coefficient	P-value
constant	5.205	0.000
WUI	0.358	0.000
DPA	0.300	0.000
lnAcres	-0.178	0.000
slope	3.28E-03	0.092
elevation	-1.55E-04	0.000
cascade slope	0.517	0.000
broadcast burn	-0.258	0.197
machine pile burn	-1.503	0.000
hand pile burn	-1.259	0.000
landing pile burn	-1.652	0.000
Obj: defensible space	-0.351	0.002
Obj: forest health	-0.303	0.000
Obj: WUI	0.205	0.024
Obj: ecosystem restoration	-0.300	0.012
harvest 4x4	-0.317	0.005
harvest 6x6	-0.120	0.203
harvest 8x8	0.251	0.133
harvest other	0.391	0.000
harvest whole tree	-0.566	0.000
brush/grass	-0.173	0.321
Doug-fir/hemlock/cedar	0.306	0.027
lodgpole	0.618	0.000
mixed conifer	0.427	0.000
FR II	0.467	0.000
FR III	0.268	0.007

FR IV	0.335	0.004
Dependent variable: lnCPA		
R-squared 0.622		
Adjusted R-squared 0.612		
N = 837		

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.

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 dummy variable in the regression model for fire treatments. After anti-log transformation, the estimated coefficient for DPA was 1.349 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 variable 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 (fuels 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 fuels reduction (t-test p < 0.02). In contrast, activities with the objective WUI were associated with significantly higher costs than those with fuels 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 et al. 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 fire escape 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 relatively high risk or 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 formally 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 et al. 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 et al. 1982) that per-acre costs generally decrease as the number of acres treated increases. For fire treatments this observation was strongly significant, but this was not the case for mechanical treatments. 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 fuels reduction objectives. All other primary project objectives were associated with lower costs than those of activities with fuels 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 and 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. 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 ensure 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 would be useful to record information on factors such as unit shape, access, distance traveled to worksite, crew composition, labor hours, mop-up days, and escape occurrences. This would enable more comprehensive analyses, and the ability to predict a greater portion of cost variability.

LITERATURE CITED

Arno, Stephen F., and James K. Brown. 1991. Overcoming the paradox in managing wildland fire. Western Wildlands. 17(1):40-46.

Bakken, Stephen. 1995. Conflicts between natural resources and structural protection. In The Biswell Symposium: Fire Issues in Urban Interface and Wildland Ecosystems. USDA Forest Service Gen. Tech. Rep. PSW-GTR-158.

Cleaves, David A. and Douglas Brodie. 1990. Economic analysis of prescribed burning. pp. 271-282. in Natural and Prescribed Fire in Pacific Northwest Forests, J.D. Walstad et al. eds. Oregon State University Press, Corvallis.

Cleaves, David A., Terry K. Haines, and Jorge Martinez. 1999. Prescribed burning costs: trends and influences in the National Forest System. P.277 in Proceedings of the Symposium on Fire Economics, Planning and Policy: Bottom Lines. USDA Forest Service Gen. Tech. Rep. PSW-GTR-173.

Davis, James B. 1990. The wildland-urban interface: paradise or battleground? Journal of Forestry. 88(1):26-31.

Davis, Kathleen M., B.D. Clayton, and W.C. Fischer. 1980. Fire ecology of Lolo National Forest habitat types. USDA Forest Service Gen. Tech. Rep. INT-122. Intermountain Forest and Range Experiment Station. Ogden, UT. 22pp.

Gonzalez-Caban, Armando, and Charles W. McKetta. 1986. Analyzing fuel treatment costs. Western Journal of Applied Forestry. 1:116-121.

Heinselman, M. L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quat. Res. 3:329-82.

Jackson, David H., Patrick Flowers, Robert S. Loveless, Jr., and Ervin G. Schuster. No date Predicting prescribed burning costs of wildlife habitat management. Fire Management Notes. 43(4):20-22.

Rich, Tim. 1984. Sources of costs associated with prescribed burning on the Powell Ranger District. Thesis, 56pp. University of Idaho, Moscow, ID.

Rideout, Douglas B. and Philip N. Omi. 1995. Estimating the cost of fuels treatment. Forest Science. 41(4): 664-674.

Snyder, Glenn W. 1999. Strategic holistic integrated planning for the future: fire protection in the urban/rural/wildand interface (URWIN). In Proceedings of the Symposium on Fire Economics, Planning, and Policy: Bottom Lines. USDA Forest Service Gen. Tech. Rep. PSW-GTR-173.

USDI/USDA. 1995. Federal wildland fire management policy and program review report. US Department of the Interior, US Department of Agriculture. Washington, D.C. 41p

THE EFFECT OF COMPLEXITY ON PRESCRIBED FIRE ACCOMPLISHMENTS IN NORTHWESTERN PONDEROSA PINE FORESTS

KENNETH HOMIK & HAYLEY HESSELN

INTRODUCTION

Profound changes in stand structure and composition in fire-adapted ecosystems throughout the western United States can be attributed to the disruption of the historic pattern of frequent low-intensity fires. Current stand conditions on roughly 40 million acres of dry site pine-fir forests virtually assure eventual occurrence of highly intense, destructive wildland fires, potentially leaving people, property and watersheds at risk (Arno 1996). The National Fire Plan of 2000 outlines approaches to protect communities and restore and maintain forest health in fire-adapted ecosystems across the interior west. The Fire Plan has established a process for prioritization of treatment activities based on current threat to resources, commodity interests, and human health and safety. The first priority is land in close proximity to communities (Forest Service Management 2002).

The criteria used to prioritize fire plan treatments will likely increase the complexity of prescribed fire management, as the strategy focuses treatments on high-risk areas in and around homes and communities. Past research has suggested that the need for the Forest Service to remain sensitive to social concerns and to protect multiple high-value resources causes managers to adopt a more conservative, risk averse management posture. Adoption of such a posture may result in escalating treatment costs (González-Cabán 1997, Cortner et al. 1990). Although these findings suggest there is a direct relationship between cost and complexity, research has not specifically addressed the effect of complexity on annual prescribed burn program accomplishments (number of acres burned per year). There has been not been an attempt to systematically quantify management complexity for use in analysis of burn program activities. Considering the emphasis on community protection of national fire policy, it is of important operational concern whether complexity associated with protection of social values restricts the potential to aggressively manage with fire in complex environments.

This study investigates the relationship between complexity and prescribed fire program operations in Forest Service owned, dry site ponderosa pine and mixed pine/fir forests. Fire management personnel were surveyed to provide accomplishment data and to quantify the complexity associated with districts' management environments. Complexity is multidimensional and can be attributed to a number of different characteristics of the prescribed fire management environment. Because of this, six sources of complexity were measured. The complexity values for each element are compared against activities to determine whether a relationship between complexity and district activities exists. In addition, fire managers were asked to rank the importance of ten factors that constrain burning operations in pine forests. Many of the factors are similar to the complexity elements and thus can serve to corroborate findings of the complexity analysis. Managers also ranked the significance of ten factors that influence the cost of burning. With these rankings, it will be possible to speculate on the cost effects of operating in a complex management environment.

This analysis is intended to serve as a pilot study and a starting point for investigating how attributes that contribute to complexity influence the ability to aggressively manage forests with fire. The resolution of the data collected was not intended for use in the development of predictive cost equations. Rather, the analysis is designed to investigate whether there are palpable relationships between complexity and activity levels in districts with active prescribed burn programs. An understanding of these relationships may assist in formulating realistic program expectations at regional and national planning levels.

BACKGROUND

Federal fire management policies adopted cost-effectiveness as a tenet of fire management strategies beginning in 1978, specifically addressing the principle of cost effectiveness in prescribed fire with the Federal Wildland Fire Policy of 1995 (Taylor et al. 1988, USDI/USDA 1995). The body of literature exploring prescribed fire economics has grown considerably in the last twenty-five years. In that time, research inquiry has evolved from investigating the cost effects of physical characteristics of burn units, to understanding the managerial and institutional factors that affect prescribed burning costs, to looking at how managers' decisions affect economic outcomes. Research up to this point has either concentrated on cost relationships or understanding the underlying behavior that determines how fire management decisions are made. However, little effort has been put into determining whether the factors that affect costs also affect yearly accomplishments, that is, how many acres are burned in the course of a year.

Economic evaluation of prescribed burn programs has proven difficult because of significant variability in prescribed burn costs within and between regions and national forests (González-Cabán and McKetta 1986, González-Cabán 1997, Cleaves 2000). In attempts to understand the source of these variations in costs, researchers initially looked at physical site parameters such as unit configuration, unit size, aspect, and slope, for example. Although hypotheses regarding the cost effect of site parameters were found to be of limited significance in explaining cost variation, such inquiries revealed two significant corollaries that persist in the literature. First, there is an economy of scale relationship in prescribed fire activities. As the size of the treatment area increases, ceteris paribus, per acre costs decrease (González-Cabán and McKetta 1986, Jackson et al. 1982, Cleaves 2000, Cleaves and Brodie 1990, Rideout and Omi 1995). Second, there is a profound lack of available cost and accomplishment records. An overriding issue that has confounded past economic analyses has been the scarcity and inconsistency of data. At present, there is no single standardized cost reporting format in use throughout the Forest Service. Such differences preclude analysis of comparable data (Wood 1988, González-Cabán and McKetta 1986, González-Cabán 1997, Cleaves 2000, Hesseln 2000).

The lack of a relationship between physical characteristics and fuels treatment costs led authors to look beyond site characteristics and investigate how political, managerial and other forces influence the cost of burning (González-Cabán and McKetta 1986, Cleaves et al. 2000). It has been speculated that a significant portion of cost variation can be explained by organizational policies and managerial perception of risk. Institutionalized rules and regulations such as smoke emission limitations and directives that do not permit fires that escape complete management control may restrict the range of alternatives available to fire managers. Directives that contribute to risk aversion may contribute to inefficient burn prescriptions by causing managers to assume a "worst case" scenario, leading to excessive use of suppression resources. A scenario-based study by González-Cabán (1997) indicates potential for significant reduction in burn costs when institutional constraints regarding risk are relaxed. The author also reaffirms the significance of the economies of scale finding, and suggests that burn programs should be planned for burn projects as large as possible within the constraints imposed by the Forest Service or air quality regulatory agencies. The study also indicates that managers act more conservatively than their perceptions may dictate. This suggests the utility of understanding the relationship between managers' risk perception and actual risk behavior.

Determining which actions fire managers take when faced with risk decisions is the objective of risk management and analysis. In prescribed fire management, risk has been defined as the potential for the realization of unwanted, negative consequences (Saveland 1985). An additional consideration in making fire risk decisions is the magnitude of the consequences that may be realized in the event of a mishap. Protection of resources affects decision-making by placing a strong influence on risk avoidance (Taylor et al. 1988). We would expect to see increasingly risk adverse postures as the number and value of these resources increases. To illustrate, consider the consequence of a fire escape that results in the loss of private property. Not only would property values be damaged, such an event has the potential to escalate into a national issue, threatening the future of the program. In such a scenario, anything less than a low risk tolerance would be negligent. Therefore risk posture and risk decisions are dependent on the number and value of resources threatened, as well as the magnitude of the consequences associated with resource damage. Social support is critical and necessary before burn programs can be successfully implemented (Manfredo et al. 1990). Yet the potential for erosion of public opinion is great given public concerns regarding safety, the risk of escape, inconvenience from smoke, reduced air quality and decreased aesthetics (Anderson et al. 1982, González-Cabán and McKetta 1986, Cleaves and Haines 1995).

The need to manage smoke in complex air quality environments may affect yearly burn activities given considerable sensitivity to community concerns (Taylor et al. 1988). Indeed, maintaining public trust in the agency's professionalism and support of prescribed burning has been shown to cause managers to avoid risk (Cortner et al. 1990). Considering the high value the Forest Service places on fostering public support, it stands to reason that managers would take action to minimize the potential for smoke impacts. One effective smoke management technique is to reduce unit size. Burning smaller units results in lower overall emissions (Prescribed Fire and Fire Effects Working Team 1985). If districts operating in complex smoke management environments utilize this technique frequently, the effect may be reduced annual accomplishments.

Other sources of complexity may cause managers to adopt conservative, risk-averse management techniques that reduce yearly activities. For example, operating in populated areas increases exposure of people, property and social resources to risk, thus increasing complexity. In such environments, managers may need to take mitigating actions to reduce hazard as well as public perception of hazard. Although the public tends to overestimate the risk from poorly understood hazards such as fire (Slovic 1980), managers may be compelled to take additional precautions based on public assessment of risk to ensure future cooperation.

This analysis seeks to determine whether managers have historically made conservative, risk averse decisions when operating in complex management environments. Findings of reduced prescribed burn activities due to complexity would suggest that activities in the future would be further reduced, as treatments are increasingly concentrated around homes and communities. We present the survey design and methodology followed by results and discussion.

METHODS

Survey Design

Burn activities are measured by the average values of three performance measures: number of acres burned per year, unit size and number of burns. These values are the dependent variables in the statistical analysis. Because of the documented shortcomings associated with the lack of accurate and reliable data, a questionnaire was designed to capture both actual and estimated values. When actual values were unavailable, estimates of activity levels were gathered from those most familiar with district operations. This approach resembles the conference method defined by Horngren et al. (2000) as a common approach for developing cost estimates. This method pools expert knowledge of managers and fire personnel.

Although complexity is not consistent over the landscape, the study approach assumes there is enough similarity within a single ranger district that managers would be able to provide an "average" description of complexity for their district. This assumption was necessary because the ranger district is the smallest administrative unit for which accomplishment data could be gathered.

Complexity is multidimensional and can be attributable to multiple characteristics that define the management environment. Six complexity elements that were thought to be significant in affecting program activities were measured. The six elements were Fuels/Fire Behavior, Threat to Boundaries, Objectives, Social Values and Improvements to be Protected, Air Quality, and Political Concerns. Elements were adapted from the Wildland and Prescribed Fire Complexity Rating Worksheet (USDA Forest Service 1999). The worksheet provides managers a method to assess the complexity of both wildland and prescribed fires. Numeric values of these six complexity elements were used as independent variables. Each attribute could then be analyzed individually to determine the effect on program operations.

In addition to the six complexity elements, district population was used as an independent variable. It is hypothesized that the source of complexity associated with social values is associated with population. If this is true, we would expect to see reduced accomplishments in high population districts because of the strong effect of social complexity elements.

Survey Methodology

Data were collected via a questionnaire mailed to Fire Management Officers (FMO) at Forest Service ranger districts throughout Regions 1, 4 and 6 (Northern, Intermountain, and Pacific Northwest Regions) during the fall and early winter of 2001-2002. Names of district FMOs were provided by the supervisor's office of each National Forest. District selection was based on the intersection of the biological range of ponderosa pine and Forest Service district boundaries. All districts within the range of ponderosa pine in Montana, Idaho, Washington and Oregon were surveyed. By analyzing activities in a specific forest type, the treatment could be held relatively constant in order to determine the effect of complexity on accomplishments.

The questionnaire followed a format similar to that used by Cleaves et al. (2000) to estimate and interpret burning costs on Forest Service lands. The questionnaire developed for this study was refined to capture technical and social complexity issues associated with burning in ponderosa pine sites in proximity to populated areas. Considerable consultation with fire managers in western Montana was used to further tailor the questions to capture the effect of the elements of interest.

Respondents were asked to provide values specific to the districts' prescribed ecosystem management burn program (EMB program) in dry-site ponderosa pine for the 10-year period between 1991 and 2000. Each district was asked to report on the average and the range of three measures of burn activities: acres per year, number of burns per year, and unit size.

A complexity element table was used to obtain a numeric value for six elements that contribute to prescribed fire complexity. The complexity elements were chosen in part on their prevalence in the literature. These factors had been cited as contributing forces in affecting the economic outcome of burn activities. There is evidence that indicates constraints imposed by air quality standards, directives to reduce escape potential, and social and political concerns affect prescribed burn costs (González-Cabán and McKetta 1986, Cleaves and Haines 1995). The elements were also components of Forest Service worksheets designed to provide managers an objective method of determining complexity for prescribed and wildland fires. For each of the elements tested, a brief written description of three complexity categories was presented for each element at each district, corresponding to low, medium and high degree of complexity. The respondent was asked to estimate the percent of their EMB program activities that was subject to each degree of complexity for each element for the last ten years, totaling 100%. For example, a respondent may report that for the Threat to Boundaries element, 50% of their activities occurred in areas of low threat, 25% in areas of moderate threat, and the remaining 25% in areas of high threat. The percent figures were then differentially weighted and transformed into numeric values, per instructions for the actual worksheet. The percent value in the low complexity category was converted to a numeric value without any weighting. Percentages in the moderate category were weighed by a factor of three, and by a factor of five for the high complexity category. These values were then summed to arrive at an overall complexity value for that element. Following the Threats to Boundaries example above, the complexity value for that element would be 50 + (3*25) + (5*25) = 250. This follows the general procedure outlined in the instructions for determining a complexity rating using the Wildland and Prescribed Fire Complexity Rating Worksheet (USDA Forest Service 1999).

District population figures were estimated using county data from the 2000 Census. In cases where districts were completely within the boundary of a single county, the total population for that county was used as the district population. In cases were districts fell within two or more counties, the percent of the district that was in each county was estimated using an ocular procedure. The percent value was then multiplied by the total population of each corresponding county. These values were added together to arrive at a total district population value.

Managers were also asked to rank the importance of factors that influence two aspects of program operations; factors that present barriers to increasing the use of prescribed fire (Program Constraints) and factors that affect implementation costs (Cost Factors). Each set of factors was presented in a table containing ten factors. Managers were asked to rank the importance of each factor on a scale ranging from zero (low importance) to four (highly important). Respondents were also asked to project which program constraints will become most significant in the next ten years.

RESULTS

A total of seventy-six questionnaires were sent to districts within the three regions. Fifty-one questionnaires were returned, for a response rate of 67%. Inferences were based on 49 questionnaires that contained sufficient data and met the criteria of having an active EMB program. For the purposes of this study, an “active” EMB program was defined as a program that burned an average of at least 200 acres per year. Two questionnaires were eliminated from analysis based on this criterion. Of the 49 questionnaires analyzed, 25 were from Region 1, seven were from Region 4 and 17 were received from Region 6.

Of the 49 responses, 13 (26.5%) reported estimated values for the activity level data (acres per year, number of burns per year, and unit size), 10 (20.4%) reported actual values, and 26 (53.1%) of the responses were a combination of estimates and actual values. Table 1 shows the descriptive statistics for the three measures of accomplishments and activities for all reporting districts. As discussed previously, the questionnaire asked respondents for average values for the accomplishment and activities data. All values reported herein are average values.

Table 1: Ecosystem burn activities, 1991-2000 (Dependent Variables)

	Mean	Median	Std Deviation	Minimum	Maximum	Range
Average Acres/YR	1616	1200	1405	200	6056	5856
Average Unit Size	779	500	972	122	4700	4688
Average # Burns/Yr	5.2	3.5	5.6	1.0	28.0	27.0

The most notable characteristic of the data is the wide range of reported values for each activity level attribute. The difference between the mean and median value of the three variables indicates that the distributions of the data are skewed toward larger values reported by outlying cases. Examination of the minimum, maximum and range demonstrate the range of burning activities throughout the sampling area. For each variable, the standard deviation is nearly as large or larger than the mean value.

Table 2 shows the descriptive statistics for each of the complexity elements. The possible range of values for any of the six complexity elements is between 100 and 500. The statistics for the population variable are also presented. Population will be referred to as a complexity element herein.

Table 2: Complexity Elements (Independent Variables)

	Mean	Median	Std. Deviation	Minimum	Maximum	Range
Threat complexity	247	220	99	100	500	400
Fire and Fuel Complexity	295	300	91	130	478	348
Objectives complexity	288	300	84	150	460	310
Social Complexity	270	260	96	110	480	370
Air Complexity	261	240	107	110	480	370
Political Complexity	304	300	90	120	500	380
Population	26,737	13,771	36,313	1,932	222,581	220,649

Threat to Boundaries, Air Quality and Social Value complexities received the lowest mean and median values. Fire and Fuels, Objective and Social complexities each have a median value of 300, with similar mean values. The narrowest range in values reported was for the Objectives element, with a range of 460. Both the Threat to Boundaries and Political complexity elements received scores that span the entire range of possible values. No element received consistently high or low scores. In general, the mean and median values are similar for each of the elements, suggesting that the data are not heavily skewed toward either high or low values. Considering this wide range of reported values, it appears that no single complexity element is consistently more or less significant in affecting burning operations across the sampling area.

There is also a considerable range in district populations throughout the sampling area. The median population (13,771) is nearly half that of the mean population (26,737), suggesting that the population distribution is highly skewed toward large values. The range of district population is nearly one-quarter of a million people, with the most populous district at 222,581 people. The large standard deviation (36,313) also demonstrates the variation in population data.

The variability in the data set restricted opportunities for statistical analysis. Linear regression and correlation were initially considered as a means of describing the association between the burn activities and complexity. However, examination of scatterplots did not reveal a strong linear relationship, even with data transfomations. As an alternative, t-tests and the Mann-Whitney U tests were used to determine whether there are differences in mean values of activity levels between two groups partitioned from each complexity element. Each of the seven complexity elements was divided into two discrete subgroups, a low (L) and high (H) complexity group. The mean values of each activity level were then compared between the low and high subgroups for each complexity element (e.g., For Political Complexity, (mean Acres Burned (H group)) vs. (mean Acres Burned (L group)). Differences in mean values of the dependent variables would suggest that level of complexity influences burn activities. Each complexity element was tested in this manner. This allowed for a systematic comparison of the seven complexity elements and determination of which elements have the greatest influence on prescribed burn operations.

The median value for each element was used as a breakpoint for the low and high complexity subgroups. This breakpoint was chosen after examination of the distribution of values for each complexity element. The Air Quality and Fuels/Fire Behavior variables displayed a bimodal distribution, with the division falling at the median value. Since the distribution of the remaining variables did not show an obvious breakpoint for grouping, the median was used for consistency and because it is not sensitive to outlying values. All districts with reported complexity values equal to or below the median were assigned to the low group, and all cases with values above the median were assigned to the high group.

Table 3. Descriptive Statistics by Complexity Subgroup

Complexity Element	Subgroup	Mean	Median	Std. Dev.	Min.	Max.	Range	Mean Diff.
Threat to Boundaries								
Acres Burned/Yr	Low	1773	1432	1411	200	6056	5856	320(L)
	High	1453	1000	1411	200	6000	5800	
Unit Size	Low	895	500	1157	50	4700	4650	243(L)
	High	652	500	724	12	3000	2988	
# Burns/Yr	Low	4.0	3.5	2.6	1.0	10.0	9.0	2.4(H)
	High	6.4	3.5	7.5	1.0	28.0	27.0	
Fuels/Fire								
Acres Burned/Yr	Low	1885	1275	1682	213	6056	5843	322(L)
	High	1312	1023	955	200	4000	3800	
Unit Size	Low	903	522	1127	40	4700	4660	271(L)
	High	632	496	748	12	3000	2988	
# Burns/Yr	Low	5.0	3.3	5.1	1.0	25.0	24.0	.4(H)
	High	5.4	4.0	6.2	1.0	28.0	27.0	
Objectives								
Acres Burned/Yr	Low	1656	1250	1411	213	6056	5843	93(L)
	High	1563	1179	1430	200	6000	5800	
Unit Size	Low	905	450	1180	40	4700	4660	302(L)
	High	603	504	549	12	2000	1988	
# Burns/Yr	Low	4.8	3.3	4.9	1.0	25.0	24.0	.9(H)
	High	5.7	4.0	6.5	1.0	28.0	27.0	
Social Values								
Acres Burned/Yr	Low	1574	1200	1458	200	6056	5856	86(H)
	High	1660	1240	1377	200	6000	5800	

Unit Size	Low	902	500	1161	50	4700	4650	258(L)
	High	644	500	714	12	3000	2988	
# Burns/Yr	Low	3.6	3.0	2.5	1.0	10.0	9.0	3.2(H)
	High	6.8	4.5	7.3	1.0	28.0	27.0	
Air Quality								
Acres Burned/Yr	Low	2115	1500	1751	200	6056	5856	1019(L)
	High	1096	1000	608	200	2500	2300	
Unit Size	Low	1140	654	1214	100	4700	4600	754(L)
	High	386	300	316	12	1200	1188	
# Burns/Yr	Low	4.0	2.0	3.0	1.0	10.0	9.0	2.4(H)
	High	6.4	4.5	7.3	1.0	28.0	27.0	
Political								
Acres Burned/Yr	Low	1736	1250	1639	200	6056	5856	294(L)
	High	1442	1190	988	200	4000	3800	
Unit Size	Low	808	500	989	12	4700	4688	74(L)
	High	734	491	969	40	4000	3960	
# Burns/Yr	Low	4.8	3.5	5.3	1.0	28.0	27.0	.9(H)
	High	5.7	3.5	6.1	1.0	25.0	24.0	
Population								
Acres Burned/Yr	Low	1849	1250	1815	200	6056	5856	476(L)
	High	1373	1200	751	213	3000	2787	
Unit Size	Low	980	600	1173	12	4700	4688	421(L)
	High	559	350	647	40	3000	2960	
# Burns/Yr	Low	4.0	2.0	5.4	1.0	28.0	27.0	2.4(H)
	High	6.4	5.0	5.6	1.5	25.0	23.5	

Table 3 shows the descriptive statistics for accomplishments and activities for each of the complexity elements by high and low complexity subgroup. The mean difference (Mean Diff.) between the high and low complexity subgroup is also presented, with an indication of the group with the greater mean value (L=low complexity groups, H=high complexity group).

The mean and median for the acres burned per year variable was larger for the low complexity subgroup for six of the seven elements. The exception was with the Social Values element, which was calculated to have a slightly greater mean number of acres burned per year for the high complexity subgroup (Low = 1,574 acres, High=1,660 acres). The largest difference in acres burned between subgroups was calculated in the Air Quality element, with a mean difference of 1,019 acres per year.

The Air Quality element also showed the greatest difference in mean values for unit size, with a mean difference of 754 acres (Low=1,140 acres, High=386). The low complexity subgroups also had larger mean unit size values for all six of the remaining elements, including the Social element. However, there were no differences in the between-groups median unit size values for the Social Values and Threat to Boundary complexity elements (High and Low median values of 500 for both elements). The median value was also larger for the high complexity subgroups of the Objectives element (L=450 acres H=504 acres). The differences in the mean and median values again illustrate the effect of outlying cases in calculating mean values. The effect of these outlying cases can also be seen in the standard deviation values for unit size, which tend to be larger than either the mean or median values.

For number of burns per year, the high complexity subgroup had a higher calculated mean value for all seven of the complexity elements. The median values were equal for both subgroups in the Threat to Boundaries and Political elements. The greatest difference in mean values was observed in the Social Values element, with an average of 3.2 more burns conducted per year for the high subgroup (Low=3.6, High=6.8)

The calculated between-group mean differences observed in the descriptive statistics suggest that there are differences in burn activities and accomplishments that can be attributed to complexity. The effects of complexities associated with air quality concerns seem to exercise considerable influence in affecting both yearly accomplishments and unit size. The effect of complexity associated with fuels and fire characteristics and population also seem to have an influence on these two activities' attributes, although the relationships are not quite as strong. Higher degrees of any form of complexity seem to increase the number of burns conducted per year, although the strength of the relationship is questionable.

Any conclusions drawn must be done so with reservation. The strength of the complexity relationship diminishes when both median and standard deviation values are considered. The influence of a few outlying cases can skew the distribution of the dependent variables and have significant influence on the mean. Despite the weight of these cases, they are valid observations that should not be disregarded for statistical simplicity. These cases help delineate and illustrate management associations that otherwise may go undetected.

Hypothesis Testing

Hypothesis testing, using inferential statistics, was used to test whether the observed differences in the descriptive statistics were significant. The Independent sample t-tests and the non-parametric alternative, the Mann-Whitney U were used to test whether there were significant differences in mean values of the dependent variables for districts grouped into "low" and "high" subgroups for each complexity element. Both tests were used because of possible limitations associated with non-normal distributions and the power to detect differences using the t-test procedure. Because the intent of the analysis was to determine the effect of complexity of activities, the three measures of activities were identified as dependent variables and the seven complexity elements were used as independent variables.

Normality was tested using the One-sample Kolmogorov-Smirnov (K-S) test. Initial results indicated that there was a high probability that the distribution of each of the dependent variables differed significantly from normal. Log transformations were successful in normalizing the distributions. Results from the K-S test indicated that the distribution for each of the complexity element groups did not deviate significantly from normal. However, splitting of the population variable did not yield normal distributions. Transformations were not successful in normalizing the distribution. Therefore, only the Mann-Whitney U test could be used when testing the population variable.

Levene's Test was used to test whether the two samples came from populations with the same variances. If the observed significance value was below 0.3, equal variances were not assumed. Results are presented for tests that were found to be significant at $p < 0.10$. Although this probability value is higher than the $p < 0.05$ value typically used to determine true significance, we that tests that yielded results at the higher probability level were suggestive of trends that would otherwise be disregarded. Results are presented and addressed in terms of the effect of the independent variable on the dependent variables.

Air Quality Values

The independent-sample t-test indicates that a significant difference in unit size in log acres was found at the $p < 0.05$ level when testing the Air Quality complexity element. Test results show that the 25 districts in the low complexity group had a calculated mean unit size of log 6.51 acres, and that the 23 districts that were grouped in the high complexity category for the Air Quality element reported a mean unit size of log 5.47 acres ($p = 0.003$). This indicates that districts grouped into the low complexity category for the Air Quality Values to be Protected element have on average a unit size that is 1.04 log acres larger than those operating in the high complexity group. The Mann-Whitney U test also corroborates these results. Mean rank for the low complexity group (N=25) and high complexity group (N=23) were 29.74 and 18.80, respectively ($p = 0.007$). This indicates that unit size is larger for those who categorize air complexity as low.

A significant difference was also detected in mean log number of acres burned per year. Mean values for the low complexity group (N=25) and high complexity (N=23) were 6.51 and 5.47, respectively ($p = 0.06$). This indicates that those reporting low complexity for the Air element burn on average .4616 log acres per year more than those in the high complexity group. This finding was again supported by the Mann-Whitney U, with a mean rank of 28.84 for the low complexity group (N=25) and 21 for the high complexity group (N=23), at $p = 0.055$. This suggests that number of acres burned is larger for districts that are characterized by low air complexity.

Fuels/Fire Behavior

Results from the t-test indicate that mean log value of unit size is larger for districts categorized in the low complexity group for the Fuels/Fire Behavior element than for the high complexity group. Mean values for the low group (N=25) and high group (N=23) were 6.34 and 5.65, respectively ($p = 0.054$), for a mean difference of log .69 acres in favor of the low complexity group. Again, the Mann-Whitney U supported these findings with a mean rank for the low (N=25) and high (N=23) complexity groups of 27.74 and 20.98, respectively ($p = 0.094$). This implies that mean unit size is larger for those grouped in the low complexity group.

Social Values to be Protected

The t-test revealed differences in log number of burns when testing the Social Values element, with a mean log value of 1.04 burns for the low complexity group (N=25) and 1.52 burns for the high group (N=23), for a mean difference of log .48 burns per year ($p = 0.044$). Again, the results were supported by the Mann-Whitney U test, with a mean rank for the low and high complexity groups of 21.5 and 28.6, respectively ($p = 0.078$). These results suggest that those grouped in the low complexity for the Social Values element conduct significantly fewer burns than those in the high group.

Population

The Mann-Whitney U test detected a difference in the mean number of burns conducted per year when population was used as an independent variable. Mean rank for the low (N=25) and high (N=24) population groups were 19.28 and 30.96, respectively ($p = 0.004$). This suggests that the mean number of burns per year is significantly lower for districts with lower populations.

Table 4 below summarizes the results of the hypothesis testing. The test results indicate which subgroup had the higher calculated mean value or mean rank for each complexity element (L=low, H=high subgroups).

Table 4. Detected Differences

Dependent Variables (Log Values used in t-test)	**Independent Variable**	**Test Results**
Acres Burned/Year	Air Quality Values	t-test: t=1.941, p=.059 (L)
		Mann-Whitney U: Z= -1.923, p=.055 (L)
Unit Size	Air Quality Values	t-test: t=3.152, p=.003 (L)
	Fuels Characteristics	Mann-Whitney U: Z=-2.706, p=.007 (L)
		t-test: t=1.952, p=.058 (L)
		Mann-Whitney U: Z=-1.673, p=.094 (L)
# Burns/Year	Social Values	t-test: t=-2.074, p=.044 (H)
	Population	Mann-Whitney U: Z=-1.763, p=.078 (H)
		Mann-Whitney U: Z=2.882, p=.004 (H)

The results from the hypothesis tests follow a number of the trends observed in the descriptive statistics. Complexities associated with air quality issues seem to have a significant effect on program operations, reducing both the total number of acres burned per year and the average unit size of burns. High degrees of complexity associated with fuels also seem to reduce unit size. Test results also suggest that high degrees of complexity associated with protection of social values and operating in highly populated environments increases the number of burns conducted per year.

The implications of these results are significant considering the expected regional and national trend of increasing management complexity. The implications are particularly strong when considering the significance of maintaining air quality standards. A gradual increase in management complexity will likely result in corresponding shifts in program operations in order to accommodate resource protection needs. These shifts will likely reduce efficiency, resulting in higher costs and slowing the pace of burn treatment.

To determine whether the delivery method may have influenced the managers' responses to the complexity analysis, many of the elements were reworded and presented again in the Program Constraints table. Additional factors were also included in the table to determine the operational significance of factors not included in the analysis. The results from the Program Constraints table were then compared with the findings of the complexity analysis to confirm consistency in the responses. Respondents also completed a Cost Factor table of factors that were considered important in influencing per-acre costs.

Program Constraints

Fuels managers were asked to rank the importance of ten program constraints that restrict the expansion of their districts' ecosystem burn program in pine stands on a five-point scale of importance. The program constraints presented were a combination of physical, environmental, social and administrative factors (see Table 5 below).

Table 5: Program Constraints

	N	Mean
Public opinion and acceptance	49	3.24
Air Quality and smoke management	49	3.06
Lack of weather windows	49	2.88
Proximity to private lands	49	2.65
Lack of personnel	49	5.61
Threat to boundaries	49	2.53
High fuel loading	49	2.45
Lack of funding	49	2.29
Not reaching objectives	47	1.68
Lack of treatment areas	48	1.50

Managers ranked Public Opinion and Acceptance as the most highly rated factor in constraining expansion of burn activities, with a mean rank of 3.24. The second highest-ranking constraint was issues regarding Air Quality and Smoke Management considerations (3.06). These were the only constraints that were rated with a mean rank greater than three. Lack of Weather Windows (2.88), Proximity to Private Lands (2.65) and Lack of Personnel (2.61) were in the five most highly ranked constraints. Threat to Boundaries had a mean rank of 2.53. The remaining factors (High Fuel Loadings, Lack of Adequate Funding, Lack of Suitable Areas for Treatment, and Uncertainty about Reaching Objectives) were all ranked below 2.5.

Parallels can be drawn between a number of the program constraints and the elements tested in the complexity analysis. In some cases, a single constraint may be relevant to multiple complexity elements. For example, the high ranking of Public Opinion and Acceptance highlights the importance of managing prescribed fire in a manner that does not jeopardize public support. Public support may be eroded by any event that causes inconvenience or jeopardizes the public's perception of management competence. Each of the complexity elements tested can be related to the importance of maintaining public support. Smoke intrusion, escaped fires, or any event that causes inconvenience or public unease can damage opinions and acceptance. The implications of this result cannot be isolated to any single complexity element, suggesting the importance of maintaining a positive public sentiment in all management actions.

The high ranking of Air Quality corroborates the findings of the complexity analysis, again suggesting the significance of air quality standards and regulations in determining prescribed burn activities. The high relative ranking of weather windows implies the importance of environmental factors that were not tested. This result suggests the importance of maximizing opportunities when windows do present themselves. Proximity to Private Lands is most closely tied with the Social Values element.

The seventh place ranking of the High Fuel Loading element is somewhat divergent from the results obtained in the complexity analysis. Fuel loadings were found to be significant if affecting unit size, while the relatively low ranking of this factor in the constraint analysis suggests that fuels are not constraining. The mean ranking of the remaining factors do not suggest any reason to question the results obtained in the complexity analysis.

When asked which constraints will become most influential in restricting burn activities in the future, managers' responses often reflected a mix of concerns. Most frequently mentioned was the significance of maintaining positive public relations and the growing significance of air quality issues. Multiple managers also expressed concern regarding the threats posed by increasing activities in urban areas, as directed by the National Fire Plan. In addition to increasing regulatory constraints, the growth of the urban interface is likely to increase smoke management complexities beyond those related directly to regulatory standards. Priority treatment areas as defined by The National Fire Plan are concentrated around communities and development. Managers expressed concern regarding the complexities of actively managing with prescribed fire in these areas, yet viewed treatment in the urban interface as a primary and central objective in fire management in the future.

Cost Factors

Table 6 represents the relative importance of ten factors fuel managers consider to be important in affecting costs. Like the Program Constraint table, these represent a mix of physical, environmental and administrative factors that affect cost. Each was ranked on a five-point scale.

Table 6: Cost Factors

	N	Mean
Min esc. Potential	49	3.16
Size of Unit	49	3.12
Weather Windows	49	2.84
Development Nearby	49	2.71
Heavy Fuel Loading	49	2.71
Cost of Labor	49	2.63
Shape of Unit	48	2.60
Agency Risk Posture	49	2.51
Compliance with Air Laws	49	2.37
Cost of Outreach	49	1.67

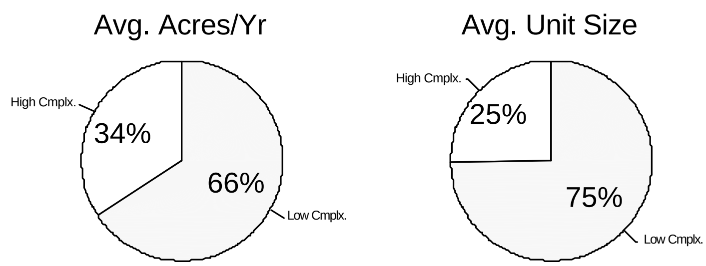
Minimizing escape potential was the highest ranked factor in affecting cost, with a mean rank of 3.16. Size of Unit was the second most important factor (3.12). These were the only two factors that received mean ranks higher than three. Lack of Weather Windows received a rank of 2.84, followed by Development Nearby and Heavy Fuel Loading, both of which were ranked equally in affecting operational costs (2.71). Cost of labor, shape of unit, agency risk posture, and compliance with air quality regulations were all ranked with a mean score between 2.63 and 2.37. Cost of Public Outreach was the only factor rated below two, with a mean rank of 1.67.

A number of the cost factors presented can be related to complexity elements tested, although some of the parallels are speculative. For example, the top ranking of the Minimize Escape factor underscores the significance of this factor, however it is difficult to attribute this to any single complexity element. The factor may be related to one or a combination of four complexity elements; Threats to Boundaries, Fuels/Fire Behavior, Social Values to be Protected and Political Concerns. The relation to the first three elements is associated with conditions that may challenge holding efforts and the need to protect adjacent values. The parallel to the Political Concerns element is related to the political fallout that can result from an escape. The second and third highest ranked cost factors, Size of Unit and Weather Windows, do not have direct corollaries to the complexity elements.

DISCUSSION

The results of this study show that complexity associated with protection of air quality resources does have a constraining effect on program operations, a trend that is expected to continue into the future. High degrees of air complexity result in the burning of smaller units, resulting in reduced yearly accomplishments and likely contributing to increases in per acre costs. Management issues associated with adherence to air quality standards will continue to test the ability of mangers to optimize burn opportunities while avoiding smoke intrusion to sensitive receptors. The adoption of increasingly stringent air quality standards will continue to add to complexities associated with protection of air resources over time. This trend will begin to constrain districts that have previously operated relatively freely, and may lead to the eventual elimination of prescribed fire in the most complex environments. The air complexity-accomplishments relationship detected in this study is illustrated by the pie charts in Figure 1 below. Each pie chart represents the sample mean value for average acres per year and unit size, with the percentage values representing the portion accounted for by each complexity subgroup (for actual values, see Table 3).

Figure 1. Air Quality Complexity



Districts that were categorized as low complexity accounted for 66% of the sample mean of 1,616 acres burned per year. For unit size, three-quarters of the population mean value of 779 acres is attributed to the low complexity group. As air quality regulations and standards tighten, more districts will find themselves operating in highly complex management environments, with a corresponding shift in burn activities. The shift will likely reduce average size of burn units, reducing the financial efficiencies associated with the economies of scale relationship.

The implications of reducing unit size on annual accomplishments only become evident when considered in conjunction with other operationally significant factors. It is possible that accomplishments could remain unchanged if there were a corresponding increase in the number of burns conducted per year to compensate for the reduction in unit size. However, no such shift in number of burns was detected in this study. This is likely due to the scarcity of available burn windows. Managers ranked availability of weather windows as the third most significant issue in constraining burn program operations. Weather alone does not adequately describe the multitude of environmental conditions that define prescribed fire prescription parameters. Temperature, relative humidity, ground level wind speed and direction, days since rain, atmospheric stability, dispersion indices, transport winds, and predicted forecast are a few of the requirements that define acceptable weather windows. In addition, fuel conditions must be within predetermined parameters to obtain desired fire behavior characteristics and meet the objectives of a burn. Alignment of these criteria yields few acceptable burn windows throughout the course of a burn season. When these windows do emerge, they tend to range in length from hours to days.

Thus, each available burn window is a scarce and highly valued opportunity. The management implication of the economies-of-scale relationship is that prescribed burn programs should be planned for burn units as large as possible (González-Cabán 1997). However, if operating in complex smoke management environments, this may not be possible. If average unit size is smaller than what would be manageable in the absence of complexity, the direct effect is a reduction in efficiency. Over the course of a year in which burn days are limited, smaller units result in fewer acres burned with a higher average cost per acre.

Compliance with air quality laws and regulations was rated second to last in the Cost Factors table, which may seem to contradict the economy of scale relationship. However, managers were likely considering the direct costs associated with complying with air quality regulations, such as the costs associated with development of the smoke management component of burn plans and the costs associated with recording and reporting emissions to air quality regulatory boards. It is quite unlikely that respondents were considering the economies of scale relationship when answering the questionnaire. Indeed, size of unit was ranked as the second most important factor in affecting cost of treatment, which would seem to support this interpretation of the rankings and further substantiate the economies of scale relationship.

The effect of air quality in determining program activities is reinforced by the ranks of both air quality concerns (ranked second) and the role of public opinion and acceptance in program operations (ranked first), and through qualitative information obtained through comments and conversations with fire managers. In discussing the need to protect air quality resources, respondents mentioned managing for two types of standards; actual, regulatory standards designed to safeguard public health and other air quality resources, as well as self-imposed standards designed to reduce inconvenience of smoke impacts to residents in the immediate vicinity of the burn area.

In terms of regulatory standards, the Clean Air Act has established National Ambient Air Quality Standards (NAAQS) to control both short- and long-term public exposure of certain pollutants, including particulate matter 10 microns and larger (PM10), and more recently particulate matter 2.5 microns (PM2.5) and larger. These are the primary components of prescribed fire smoke that contribute to air quality degradation. The Environmental Protection Agency (EPA) has established monitoring stations in areas that have been found to be in consistent violation of the established standards of air quality. When an area exceeds these standards, the use of prescribed fire may be limited in order to allow air quality to improve to the standards established by the EPA.

Self-imposed standards refer to a district's attempt to reduce inconvenience from residents in close proximity to the smoke source. An example may be a cluster of houses down drainage of a prescribed burn that may become severely smoked-in as a result of a district's burn activities. These locally significant smoke events may affect relatively few people, yet the impact to those individuals is much more acute than the dispersed impacts associated with violations detected at air quality monitoring stations miles from a burn. Managers are sensitive to community concerns associated with smoke from prescribed burning, reflecting the agency's sensitivity to smoke impacts (Cortner et al. 1990). Considering that pine communities generally occupy low elevation sites, where National Forest lands are in close proximity to developed lands, smoke impacts from these treatments are more likely. Thus, even if there is no violation of standards set by the EPA, managers may find it necessary to take mitigating actions to reduce smoke emissions in order to reduce local inconvenience from smoke and maintain public support.

The results from the complexity analysis also suggest that high levels of complexity associated with the Fuels Characteristics element resulted in reduced unit size. A possible explanation for this shift to smaller unit size may be the adoption of more conservative management techniques to reduce escape potential. A conservative approach may be prudent because of the proximity to residential development and population centers where resource values tend to be high. Smaller units would reduce the amount of perimeter, facilitating holding operations. However, the results from the activities analysis are somewhat ambiguous. Only average unit size was found to be significant in the complexity analysis, with no differences detected in acres per year or average number of burns per year. This raises the question whether the result is valid or was found to be significant due to error in the survey method. Furthermore, the results of the Program Constraints analysis suggest that fuels conditions are not a significant factor in affecting accomplishments. High fuel loading was ranked seventh out of ten in affecting burn operations in the Program Constraint table. This seems at odds with findings of the complexity analysis. The lack of substantiating results suggests further research is necessary.

Similarly, it is difficult to infer the implications of the other differences in activities detected in the complexity analysis. Both the Social Values and Population elements were found to affect the number of burns conducted per year. The results from the statistical analysis suggest that districts with low complexity values (or population values) for these elements conduct fewer burns per year than districts with high values. This would suggest that districts that are sparsely populated with few threatened social resources are able to take advantage of the economies of scale relationship and conduct fewer, larger burns. However, no significant differences were detected in average unit size or in average acres per year.

Although it is difficult to speculate on the operational significance of these elements, the rankings of the program constraints indicate that protection of private resources does affect program operations and contribute to costs. Proximity to private lands was ranked forth overall. Both this constraint and the descriptions of the Social Values element involve some threat to people, property or social resources. Similarly, increases in population would likely expose more people, and the associated public resources, to fire threats. Thus the two complexity elements (Social Values and Population) as well as the program constraint (Proximity to Private Lands) are similar. Although the complexity analysis did not yield a strong indication of the operational effect of these elements, inductive reasoning would lead to the conclusion that protection of social values has had an effect on prescribed fire operations.

The complexity values used in the analysis were based on manager's rating of an "average" complexity level for each element. Managers noted the difficulty in generalizing the district's management environment because of significant variations in the social, political, administrative and environmental attributes throughout a district, even within similar vegetative zones. This is not surprising, considering that districts typically encompass hundreds of thousands of acres, covering many miles and many different types of social and environmental conditions. This suggests that complexity is too site-specific for generalization, and that complexity may only be accurately quantified when measured on a case-by-case basis.

There may also be issues with relating activity levels to seven elements. In reality, explaining differences in activities on the basis of a handful of elements oversimplifies the complicated decision process that ultimately determines prescribed fire operations. This attempt to quantify and model these relationships required a simplified approach that may have missed many of the actual mechanisms that dictate prescribed fire operations. Management actions are based on the interrelation of social, political, administrative and environmental considerations. This complicates any effort to quantify complexity for comparative study difficult.

Variation in the reported complexity values between districts may have also obscured actual complexity-activities relationships. A portion of this variation may be attributed to the subjective sampling method that was used. Managers were asked to provide complexity values for their districts, however there was no baseline datum from which managers could gauge their response. Said differently, managers were not able to compare their district's management environment to an established standard. The accuracy of values would be dependent on the manager's knowledge of the range of complexity conditions that exist throughout the sampling area. Relative values may be quite accurate within a small geographic area such as a National Forest because of the managers' knowledge of issues common to an administrative unit. However, it was likely difficult for respondents to gauge their districts' complexity level relative to that of districts in other National Forests and regions hundreds of miles away.

The expert opinion method used here alleviated some of the problems associated with the lack of information regarding prescribed fire activities. However, the quality and the accuracy of the data are dependent on the knowledge and memory of the respondent, introducing a potential source of error. Managers were allowed to provide estimated activities values if actual values were not available. It was assumed that the estimated activities values would be a close approximation of the actual values; sufficiently accurate to reveal trends in activities. However, there is some reason to question the accuracy of estimates. In one case, two responses were received from a single district; one reporting actual values and the other reporting estimated values. For average number of acres burned per year, the estimated value was nearly 500% greater than the actual value (1000 acres vs. 213 acres). This suggests that there may be some reliability issues associated with use of historic activities data from memory. It is impossible to know how accurate estimated values were for the entire sample. However, considering that 80% of the data used in the accomplishments analysis were based on estimated or combination of estimated and actual values, there is some suspicion as to the reliability of the data. This variability can be attributed to inherent limitations associated with survey studies that rely on "self-report" data and the problems associated with the commitment of "honest" errors of omission, confusion, or false memory (Woods 2003).

Although comments and conversations with managers suggest a significant reduction in management opportunities as population increases, this analysis did not show a strong relationship between district population and accomplishments. The lack of statistically significant differences using the population variable may be the result of problems associated with ascertaining accurate district population values. Deriving accurate values is complicated by the fragmented land ownership pattern that exists throughout the west. Ranger districts are frequently composed of multiple parcels or islands of land, often separated from one another by many miles. It is not uncommon for a district to administer lands that fall within two or more counties. Thus it is difficult to derive an accurate population figure for individual districts based on county census data. Furthermore, without using a finer resolution of population data, it is impossible to accurately determine the populations that may be impacted by burn activities due to differing population densities within a district. The method used assumes that each resident of a county has the same probability of being impacted by burn operations of a given district. This is certainly not the case, considering most populations are grouped in cities, towns and communities that may not be in a district's "impact zone." Indeed, due to the nature of smoke dispersal patterns, district operations may impact more residents of adjacent counties rather than the county in which the district actually lies.

There is some issue associated in using the t-test and Mann-Whitney U with variable data. As reported in the results section, the range of reported activities and complexity values was quite large, with standard deviation values nearly as large or larger than the mean values. Both the sample variance and the number of cases in each group are used in the calculation of the t-statistic. The larger the sample variance, the less likely we will be able to reject the null hypothesis. This inability to detect actual differences in the sample means is further compounded when the sample size is small. Thus the combination of these two factors likely reduced the ability of the t-test to detect differences in the sample means of the two groups, even when these differences in dependent variables is large. Although use of the Mann-Whitney U alleviates some of the problems associated with testing of samples that violate assumptions necessary for use of a parametric test, the non-parametric tests are not as powerful at detecting differences between groups (Norušis 2000).

CONCLUSION

Study results indicate that complexities associated with air quality standards have the greatest impact on district burn activities. Both actual, regulatory smoke management standard and self-imposed standards will continue to challenge managers to actively utilize prescribed fire as a component of forest stewardship activities. The challenges these standards present will likely reduce efficiencies to such a degree that prescribed burning may be abandoned in the most complex management environments. Although mechanical treatments may provide a surrogate to prescribed fire for reducing forest fuels and recreating forest structure, it cannot emulate the unique biophysical responses induced by fire. Managers will be left to decide whether the ecological benefit of returning fire is worth the financial costs and risk associated with use of the practice.

The majority of complexity elements tested did not yield discernable, conclusive complexity-accomplishment relationships. Inherent limitations in survey methodology and the difficulty in capturing the multifaceted components of complexity may account for the results rather than a lack of actual causal relationships. Prescribed fire managers are quick to point out the power of social concerns in determining whether prescribed fire is an appropriate management tool, and if so, how it will be managed. The techniques and precautions used are contingent on the value of the resources that are threatened, and the magnitude of subsequent consequences in the event of resource damage. Managers must not only consider the market value of threatened resources, but also weigh the consequences of their actions in terms of public acceptance. The publics' discomfort with perceived risk and the psychological concerns associated with smoke and threat of escape is likely to be much greater than the actual risk. Any precaution that is adopted to safeguard public resources or reduce public unease that would not be taken in the absence of social concerns can be attributed to social complexity. Remaining sensitive to these perceptions and reacting to public concern will likely come at the expense of efficiency.

As managers look to the future of fire management, it is likely that the need to protect social values will increasingly dictate management activities. National fire policies are now directing treatments into populated areas in community protection efforts. These areas should be priorities for protection from wildfire events, as they represent a significant concentration of high resource values and are associated with public safety. However, the same characteristics that necessitate protection also complicate active management. Future policies and activities will reflect the willingness of the public to accept the risks and inconveniences associated with prescribed fire.

Future research that seeks to better understand the complexity-accomplishment relationship should limit the geographical scale of sampling. Although this study attempted to reduce variability in treatment by concentrating on a single forest type, there are certainly ecological and climatic variations within the sampling area that account for some of the differences in accomplishments. An in-depth analysis of activities at a finer scale would reduce the variability associated with administrative and policy differences between multiple administrative units.

A case study approach that utilizes a qualitative analysis method would allow for a thorough examination of the relationships that determine activities and economic outcomes. The multitude of factors and considerations that enter into the decision matrix for any individual burn are difficult to analyze quantitatively, and any effort to do so likely obscures the nuances that ultimately determine management actions. Each burn site has a set of unique characteristics that define the management actions and precautions necessary to protect resource values in the immediate area. A concentrated study would allow for detailed assessment of all the factors that enter into the decision-making process and the ultimate effect on the economic outcome burn activities. The drawback of the case study approach is that results cannot be generalized beyond that case (Doyle 2003). However, the context-specific nature of prescribed fire makes development of decision-making models that account for more than a small portion of economic outcomes difficult. Attempts to generalize the factors that account for prescribed fire activities can at best hope to reveal fundamental relationships that define activities, as has been done here. Analyses that look beyond these fundamental relationships will need to reduce the scale of sampling to account for the multitude of factors that ultimately determine management actions.

Above all, researchers and policy makers should recognize the full range of complexities associated with prescribed fire management. Fire managers are quick to call attention to the innumerable sources of variation within the prescribed fire environment, many of which are inconsistent across the landscape and unpredictable in nature. Decisions and activities are dependent on a stochastic set of factors that include climatic, physical, social, ecological, political, and administrative considerations, to name but a few. Although these factors will continue to contribute to variations in costs and accomplishments and will always be inherent in prescribed fire management, investigation into the relationships that define prescribed burn activities is certainly warranted. However developing a solid understanding of the complexity-accomplishment relationships that drive prescribed fire programs will likely continue to befuddle traditional economic analysis.

LITERATURE CITED

Anderson, L. M., Daniel J. Levi, Terry C. Daniel, and John H. Dieterich. 1982. The esthetic effects of prescribed burning: A case study. Rocky Mountain Forest and Range Experiment Station, USDA Forest Service. Res. Note RM-413. 5p.

Arno, S. F. 1996. The concept: Restoring ecological structure and process in ponderosa pine forests *In* The Use of Fire in Forest Restoration. Colin C. Hardy and Stephen F. Arno, eds. Ogden, Utah. USDA Forest Service Gen. Tech. Rep. INT-GTR-341.

Cleaves, David A. and Douglas Brodie. 1990. Economic analysis of prescribed burning. pp. 271-282. *In* Natural and Prescribed Fire in Pacific Northwest Forests, J.D. Walstad et al. eds. Oregon State University Press, Corvallis.

Cleaves, D. A., and T.K. Haines. 1995. Regulation and liability risk: Influences on the practice and the pricetag of prescribed burning. Environmental Regulation & Prescribed Fire: Legal and Social Challenges, Tampa, FL, Center for Professional Development, Florida State University.

Cleaves, D. A., T. K. Haines and J. Martinez. 2000. Influences on prescribed burning activity and costs in the national forest system. USDA Forest Service SRS-GTR-37. 34p.

Cortner, H. J., Jonathan G. Taylor, Edwin H. Carpenter, and David A. Cleaves. 1990. Factors influencing Forest Service fire managers' risk behavior. Forest Science 36(3): 531-548.

Doyle, James K. 2003. Chapter 10: Introduction to survey methodology and design. March 2, 2003. http://www.wpi.edu/Academics/Depts/IGSD/IQPHbook/ch10a.html

Forest Service Management. 2002. Protecting people and sustaining resources in fire-adapted ecosystems: A cohesive strategy. February 4, 2002. http://www.fireplan.gov/cohesive.cfm.

González-Cabán, A. 1997. Managerial and institutional factors affect prescribed burning costs. Forest Science. 43(4): 535-543.

González-Cabán, A, and C. W. McKetta. 1986. Analyzing fuel treatment costs. Western Journal of Applied Forestry. 1:116-121.

Hesseln, Hayley. 1999. The economics of prescribed burning: A research review. Forest Science. 46(3): 322-334.

Horngren, C., G. Foster and S. Datar. 2000. Cost accounting: A managerial emphasis. New Jersey. Prentice-Hall, Inc.

Jackson, D. H., Patrick Flowers, Robert S. Loveless Jr., and Ervin G. Schuster. 1982. Predicting prescribed burning costs of wildlife habitat management. Fire Management Notes. 43(4): 20-22.

Manfredo, M.J., M. Fishbein, G.E. Haas, and A.E. Watson. 1990. Attitudes toward prescribed fire policies. J. For. 88(7): 1841-1851.

Norušis, M. J. 2000. SPSS 10.0 Guide to data analysis. New Jersey. Prentice-Hall, Inc.

Prescribed Fire and Fire Effects Working Team. 1985. Prescribed fire smoke management guide. PMS 420-2. NFES 1279.

Rideout, Douglas B. and Philip N. Omi. 1995. Estimating the cost of fuels treatment. Forest Science. 41(4): 664-674.

Saveland, J. M. 1985. Risk in fire management. *in* Fire Management: the Challenge of Protection and Use. Utah State University. Intermountain Society of American Foresters Intermountain Region.

Slovic, P., B. Fischhoff and S. Lichtenstein. 1980. Fact and fears: Understanding perceived risk. *In* Schwing, R. C. and Albers, W. A. Jr. eds. Societal Risk Assessment-How Safe is Safe Enough? New York: Plenum Press. Pp. 181-214.

Taylor, J. G., Edwin H. Carpenter, Hanna J. Cortner, and David A. Cleaves. 1988. Risk perception and behavioral context: USForest Service fire management professionals. Society and Natural Resources 1: 253-268.

USDI/USDA. 1995. Federal wildland fire management policy and program review report. USDepartment of the Interior, US Department of Agriculture. Washington, D.C. 41p USDA Forest Service. 1999. Selway-Bitterroot wildland fire use guidebook. Internal Agency Publication.

Wood, D. B. 1988. Costs of prescribed burning in southwestern ponderosa pine forests. Western Journal of Applied Forestry 3(4): 115-119.

Woods, D. W. Handbook for IQP Advisors and Students. Chapter 10: Introduction to survey methodology and design. March 1, 2003.
http://www.wpi.edu/Academics/Depts/IGSD/IQPHbook/ch10a.html

ECONOMIC ANALYSIS

Our second objective was to assess non-market costs and benefits associated with fuels treatments. We evaluate non-market effects associated with fuels management methods to gain a better understanding of the economic in addition to the financial effects. Because social values influence total costs and benefits, inclusion of such values will better identify and facilitate the comparison of cost-effectiveness of alternative fuels management techniques. We estimate social perceptions with respect to the effects of prescribed burning such as air quality issues, related health effects, and visual impairment from smoke. Similarly, we assess public perceptions and attitudes with respect to the visual and perceived ecological effects of mechanical treatments.

We also estimate recreation values and changes therein resulting from alternative fuels treatment methods. Our focus was to identify factors that affect social perceptions and thus social acceptability for management projects and federal policy. Results will greatly enhance fire managers' abilities to implement successful projects by reducing social opposition and possibly long-run costs. Results will also be useful in determining the value of education with respect to fuels treatments, including issues such as smoke and risk associated with wild and prescribed fires, and visual, ecological and financial tradeoffs among fuels management techniques.

THE EFFECTS OF FIRE ON RECREATION DEMAND IN MONTANA

HAYLEY HESSELN, JOHN LOOMIS & ARMANDO GONZÁLEZ-CABÁN

INTRODUCTION

Wildfire is becoming a heightened concern for the public, scientists and policy makers throughout the western states as fuel loading increases to unnaturally high levels, giving rise to more frequent fire occurrence and greater severity (Arno and Brown 1991). Because social values can be affected by fire, and are an important economic component of the decision-making process, it is important for fire managers to have an understanding of the magnitude and extent of such effects. For example, although prescribed burning may appear to be more cost-effective than mechanical fuels treatments, fire use may diminish social values as a result of smoke and non-aesthetically pleasing landscapes. When these social values are included in the decision-making process, mechanical fuels treatments may prove to be more economical.

Although such values are important to include, there is a dearth of information with respect to the affects of fire on recreation values and demand. Notwithstanding, several scientists have made important inroads into assessing values. Vaux et al. (1984) used a contingent value approach to estimate the economic effects of burned areas on recreation demand. Results indicated that higher intensity fires negatively affected recreation values. Flowers et al. (1985) conducted similar research with respect to the northern Rocky Mountains and determined that there was no clear consensus regarding the treatment of fire duration. Englin et al. (1996) and Boxall et al. (1996) used the travel cost method (TCM) to assess changes in canoeing value in Manitoba, Canada as a result of fire. Finally, the TCM was used by Loomis et al. (2001) to evaluate fire effects on hiking and mountain biking in Colorado. They found that there were differential effects on hiking and mountain biking visitation as a result of different fire ages and the presence of crown fires. Similarly, net benefits were also affected by crown fire and prescribed fire.

To assess the effects on value and demand for hiking and biking in Montana, we replicated the Colorado survey in Montana (Loomis et al. 2001). Because the survey was designed to estimate demand for recreation in National Forests, we focused on recreation demand for hiking and biking on the Lolo, Bitterroot, Flathead and Helena National Forests. We provide an overview of the methodology, followed by a discussion of the model and our hypotheses. Lastly, we present the results of the regression models and our conclusions.

METHODOLOGY

Loomis et al. (2001) conducted a travel cost survey in Colorado to determine how fire affected hiker and mountain biker demand in burned areas. We use the same survey and travel cost methodology to estimate the demand for recreation in Montana (see Appendix B). The travel cost method (TCM) is a statistical technique that uses variations in visitors' travel costs as a measure of price and trips taken as quantity to trace out a demand curve. From the demand curve, individual benefits, or consumer surplus, is calculated as the area under the demand curve between visitors' current price and a price that would drive visits to zero (i.e., the choke price). TCM, which is a federally recommended technique, is widely used by federal agencies (US Water Resources Council 1979).

We measure actual and intended trips as a function of actual site attributes such as elevation, trail length and elevation gained, and fire characteristics including fire age, percentage of burn observable from the trail, presence of a crown fire, and demographics and travel cost information. Respondents were asked to provide travel cost data including gas costs, camping costs and other travel related expenditures.

We use a count data TCM model because the number of trips taken is a non-negative integer and statistical efficiency is improved by using such a specification (OLS regression does not). To account for the possibility that the mean of visitor trips is not equal to its variance, we use a negative binomial count model.

Fire Effects TCM

We specify the fire effects model by Equation [1],

$$
\begin{aligned}
TTRIPS = ß_0 + ß_1(Burnobs) + ß_2(Acres) + ß_3(AGE) + ß_4(CROWN) + \\
ß_5(CROWNFIREAGE) + ß_6(ELEV) + ß_7(FIREAGE) + ß_8(TCOST) + ß_9(TCOST^2) \\
ß_{10}(GENDER) + ß_{11}(GROUPSIZE) + ß_{12}(HYPAC) + ß_{13}(INC) + ß_{14}(LP) + ß_{15}(miledirtrd) + \\
ß_{16}(TCCROWN) + ß_{17}(TCFIREAGE) + ß_{18}(TRAVTIME) + ß_{19}(TTBUD) + ß_{20}(BIKE) \\
+ß_{21}(BIKETC) + ß_{22}(BIKECROWN) + ß_{23}(BIKECROWNFIREAGE) + ß_{24}(BIKEFIREAGE) \\
+ ß_{25}(BIKETCCROWN) + ß_{26}(BIKETCFIREAGE) \qquad [1]
\end{aligned}
$$

with model variables and definitions given in Table 1.

Table 1. Model variables and descriptions

Variable	Description
TTRIPS	Total number of trips taken.
BURNOBS	Percentage of fire observable on trail.
ACRES	Number of acres burned.
AGE	Respondent's age (yr).
CROWN	Dummy variable, 1 = crown fire.
CROWNFIREAGE	Interaction between crown fire and fire age.
ELEVATION	Trailhead elevation above sea level (ft).
FIREAGE	Age of fire - negative values: -10 is 10-yr-old, -20 is a 20-yr-old fire.
TCOST	Individual share of travel costs ($).
TCOST2	Travel cost squared.
GROUPSIZE	Number of people in the group.
HYPACT	Dummy variable: 1 = hypothetical response to contingent scenario, 0 = actual trip taken.
INCOME	Household income of survey respondent ($).
LP	Dummy for presence of lodgepole pine (1 = lodgepole pine).
MILEDIRT	Miles of dirt road traveled to site.
TCCROWN	Interaction variable between total cost and crown to test the effects of crown fires on consumer surplus.
TCFIREAGE	Interaction between travel cost and fire age to test whether value per trip changes with fire age.
TRAV	Travel time to the site (hours).
TTBUD	Total time budget available for non-winter vacation; weekends plus paid vacation (days).
BIKE	Dummy variable for bikers (1 = biker).
BIKETC	Interaction between travel cost and bikers.
BIKECROWN	Interaction between crown fires and bikers.
BIKECROWNFIREAGE	Interaction between bikers and aging crown fires.

BIKEFIREAGE	Interaction between bikers and fire age.
BIKETCCROWN	Interaction to measure the effects of crown fires on bikers' consumer surplus.
BIKETCFIREAGE	Interaction to measure the effects of fire age on bikers' consumer surplus.

Benefit Calculations

The model is designed to calculate consumer surplus and to indicate whether fire effects have an influence on visitation and value of trips taken. Consumer surplus is the area under the demand curve between the current price and choke price. We calculated consumer surplus as $1/((\beta_8 + \beta_9)$ because we use a count data model which is equivalent to a semi-log demand function (Loomis et al. 2001).

To test whether the age of a fire (e.g., FIREAGE) has a statistically significant effect on net benefits, we interacted FIREAGE with the travel cost variable TCOST to create a term called TCFIREAGE. Specifically, if fire age has an effect on the price slope of the demand curve, the coefficient β_{17} will be significantly different from zero. Using the same logic, we constructed an interaction term of travel cost and the dummy variable for crown fire to test whether the presence of a crown fire has a statistically significant effect on consumer surplus. The effects of crown fires and fire age on the consumer surplus calculations for hiking trips are given by Equations [2] and [3].

$$1/(\beta_8 + \beta_9 + \beta_{16}) \quad [2]$$

$$1/(\beta_8 + \beta_9 + \beta_{17} * FIREAGE_t) \quad [3]$$

Similarly, we tested the effects of crown fire and prescribed fire on bikers' net benefits by interacting the dummy variable for bike (BIKE) with crown fire (CROWN) and total cost (TCOST) to create the term BIKETCCROWN. We also tested the effects of prescribed fire over time on biker consumer surplus (BIKETCFIREAGE). Consumer surplus calculations for bikers as affected by crown fires and prescribed fires are indicated by Equations [4] and [5].

$$1/(\beta_8 + \beta_9 + \beta_{16} + \beta_{21} + \beta_{25}) \quad [4]$$

$$1/(\beta_8 + \beta_9 + \beta_{17} * FIREAGE + \beta_{21} + \beta_{26} * FIREAGE_t) \quad [5]$$

Hypothesis Tests

Using t-tests on each of the variables in equation (1), we tested for the significance of the fire effects variables. Specifically, we tested whether FIREAGE, CROWN, and CROWNFIREAGE were significantly different from zero. Similarly, we tested for differences between bikers and hikers using BIKEFIREAGE, BIKECROWN and BIKECROWNFIREAGE. Finally, we used regression results to estimate the effects of fire on value per day, and the number of trips taken over time. Hypotheses are listed in Equations [6a] – [6f].

$$H_0 = \beta_7\,(FIREAGE) = 0, \text{ versus } H_a = \beta_7\,(FIREAGE) \neq 0 \quad [6a]$$

$$H_0 = \beta_4\,(CROWN) = 0, \text{ vs. } H_a = \beta_4\,(CROWN) \neq 0 \quad [6b]$$

$$H_0 = \beta_5\,(CROWNFIREAGE) = 0, \text{ vs. } H_a = \beta_5\,(CROWNFIREAGE) \neq 0 \quad [6c]$$

$$H_0 = \beta_{24}\,(BIKEFIREAGE) = 0, \text{ vs. } H_a = \beta_{24}\,(BIKEFIREAGE) \neq 0 \quad [6d]$$

$$H_0 = \beta_{22}(BIKECROWN) = 0, \text{ vs. } H_a = \beta_{22}(BIKECROWN) \neq 0 \quad [6e]$$

$$H_0 = \beta_{23}(BIKECROWNFIREAGE) = 0, \text{ vs. } H_a = \beta_{23}(BIKECROWNFIREAGE) \neq 0 \quad [6f]$$

Data Collection

Sample design

Recreation sites were stratified by acres burned and year since fire. We sampled size classes including C (10-99 ac), D (100-299 ac), E (300-999 ac), F (1,000-4,999 ac) and G (5,000+ ac). Fire age was recorded as time since fire, which included zero representing fires that occurred the year of the survey (2000), and older up to 50 yr. Fire age classes included 1-5, 6-10, 11-20, 21-30, 30 + yr. Equivalent unburned sites were sampled on each of the National Forests to provide a control and to represent the sixth age category. Four National Forests in Montana were selected for this study based on these criteria. They include the Bitterroot National Forest, the Flathead National Forest, the Lolo National Forest, and the Helena National Forest. We contacted district rangers, recreation managers, and fire management personnel to locate recreation areas that exhibited evidence of both prescribed and wildfire, as well as areas that did not show evidence of fire to be used as control sites (we focused on recreation activities associated with trail use, and for this reason, we were unable to statistically sample sites due to the limited number of recreation trails that were burned by either wildfire or prescribed fire. For this reason, results may not be representative of recreation use on all National Forests in Montana). Forest trails were selected based on recreation use (hiking which includes camping and sightseeing, and biking), fire history (prescribed and wildfire), fire size (classes C-G), and logistical viability. Finally, we sampled areas with heavy, moderate, and light recreation use.

Sites were sampled for a total of 25 days in 2000. Because of fire activity in the Bitterroot Valley, and in Montana in general, all recreation areas were closed across the state for use beginning in August. Prior to closure we sampled 11 days. After fire restrictions were relaxed in September, we sampled an additional 14 days. Final sampling occurred in 2001 over 34 days between June and August inclusively. We sampled on both weekdays and weekends to capture the widest variety of forest recreation users.

Surveyors collected site attributes pertaining to each site, which were verified by Forest Service personnel. Attributes were chosen based on those that were significant in past forest recreation studies (Englin et al. 1996, Loomis et al. 2001). Data collected included elevation (ft), elevation gained on trail (ft), dirt road access (mi), presence of scenic vistas (1 = yes, 0 = no), presence of water (1 = yes, 0 = no), trail length (mi), and activity use. We verified site characteristics, such as elevation, trail length, and elevation gained using topographical maps and GIS applications.

With respect to fire characteristics, we collected data pertaining to the burn size (acres), the percentage of the burn that could be viewed from the trail, the percentage of the trail affected by the burn, fire intensity (flame length), and fire age (years since fire). Forest Service personnel and GIS applications were used to verify these data. Fire sizes ranged from 15 to 250,000 ac. With respect to fire age, the oldest fire was 24-yr old and the newest, one year. Sites sampled that were not affected by fire were coded as 50-yr old.

Survey Structure

Interviewers intercepted one individual from each group at each trailhead. The interviewer introduced herself and gave her university affiliation and purpose. Respondents were given a questionnaire with a postage paid return envelope. Questionnaires were distributed to individuals 18 yr or older. Respondents were asked to provide their primary recreation activity and attributes of the site that were important to them. They were also asked to provide travel time, travel distance, and travel cost to the site. Travel cost included gas cost, camping fees and other travel related costs such as hotels. Individuals recorded the number of trips taken to the site in the last 12 months. Finally, respondents were asked to record the number of trips they would take given an increase in trip costs ($3, 7, 9, 12, 15, 19, 25, 30, 35, 40, and 70). This provided additional price variability to supplement the natural variability in travel costs due to different originations.

Stated preference analysis was based on three photos that depicted different fire scenarios and ecological conditions. Each survey booklet included three photographic scenarios depicting areas that had been burned to various degrees. Respondents were asked how their visitation to each site would change if half the trail they were on, resembled that of the photo. This enabled us to efficiently convey the effects that high-intensity crown fires, light prescribed burns, and older high intensity burns have on recreation demand. We based the stated preference analysis on three fire scenarios using color photographs of the following: (1) High-intensity crown fire (crown fire): blackened, standing trees with little greenery where the fire was two years old, (2) Light prescribed burn (Rx Burn): underbrush burned, trees burned on the lower portion of the trunk, reddish needles on lower branches, green needles on the majority of the trees, where the burn was two years old, and (3) High-intensity 20-yr old burn (old crown fire): standing dead trees, white trunks, downed trees mixed with new greenery.

Stated preference and revealed preference data were combined using a panel approach (Englin and Cameron 1996). Given the four scenarios—crown fire, Rx burn, old crown fire, and increased cost per trip—we were able to stack the database into panels. The four scenarios represented stated preference data, while the actual observations collected from the survey respondents represented revealed preference. Therefore each respondent provided six observations. The first and second panels represented actual trips taken in the previous year and the current year and were coded with a dummy variable, HYPAC = 0, to reflect observed behavior. For these observations, site data and fire attributes were recorded as actual observations and actual fire history. Panels three through five represented, for each individual, stated preference behavior relating to the three fire scenarios –crown fire, Rx burn, and old crown fire. Site characteristics were recorded as actual site attributes, however, we coded fire history according to fire characteristics relating to each of the three scenarios. For example, fire age for the high intensity crown fire was 2-yr old, the prescribed fire was 2-yr old, and the old crown fire was 20-yr old. In each of these three cases, the percentage burn observable (BURNOBS) was recorded as 50% to reflect 50% of the trail in this condition. Finally, the last panel included contingent behavior based on increased travel costs. In this panel, we used actual fire history and site characteristics. The final four panels were coded as HYPAC = 1 to reflect stated preference.

RESULTS

We made a total of 1,074 visitor contacts of which there were 24 refusals. In total, we distributed 1,050 questionnaires, 559 (53% response rate) of which were returned after first and second postcard reminders.

Of the visitors to the 22 sites, approximately 78% were hiking, camping and sightseeing. The next largest categories were biking at 10%, fishing at 7%, and swimming and water related activities at 5%. Group size was approximately three individuals who stayed onsite an average of 12 hours. The average distance traveled onsite was 5.8 mi. The average visitor spent $12.60 in travel costs getting to the site and traveled a distance of 98.6 mi. Visitors were 51% male with an average age of 39 yr. Average household income was

$55,576, while the average education level was a baccalaureate degree. Averages are summarized in Table 2.

Table 2. Descriptive statistics of travel survey for Montana

Variable	Montana
Site and visitor statistics	
Travel distance to site (mi)	98.6
Travel time to site (hr)	1.6
Gas cost per individual ($)	12.60
Time onsite (hr)	11.9
Miles traveled onsite	5.8
Group size (# persons)	3.2
Fire Statistics	
Average fire age (yr)	12
Average fire size (ac)	9,344
Contingent Behavior	
Total average trips	12.3
Trips for crown fire	10.6
Trips for Rx burn	12.9
Trips if old crown fire	11.0
Demographics	
Percent females	48.8
Respondent age	39
Education (yr)	16
Percent retired	10
% members of environmental organization	30
Years at current residence (yr)	11
Household income	$55,576

Individuals took an average of 12.3 trips/yr. When respondents were asked to provide the number of trips taken given the three scenarios; the averages reported were 10.6 for the crown fire, 12.9 for the Rx burn, and 11.0 for the old crown fire. Regression results are displayed in Table 3.

Table 3. Regression results for Montana

	Coefficient (Std. Err)	P-value
Consumer Surplus		
Travel cost	-0.0270 (0.0072)	0.000
Travel cost squared	4.58E-05 (1.14E-05)	0.000
Bike	0.9722 (0.2785)	0.000
Bike x Travel cost	-0.0541 (0.0555)	0.329
Value and Fire Effects		
Travel cost x crown	0.0035 (0.0047)	0.450
Travel cost x Rx burn	3.60E-05 (0.0003)	0.906
Travel cost x bike x crown	0.0872 (0.0714)	0.222
Travel cost x bike x Rx burn	-0.0003 (0.0067)	0.959
Fire Effects		
Fire age	-0.0143 (0.0054)	0.008

Crown fire x age	0.0235 (0.0087)	0.007
Crown fire	2.34E-01 (0.1802)	0.193
Acres burned	-6.56E-05 (2.28E-05)	0.004
Bike x crown fire	-0.1823 (0.4908)	0.710
Bike x crown fire x fire age	-0.0238 (0.0317)	0.453
Bike x fire age	0.0197 (0.0195)	0.312
% Burn observable	0.0064 (0.0026)	0.015
Site Characteristics		
Elevation	0.0002 (0.0002)	0.317
Dirt road access	0.0346 (0.0319)	0.277
Lodgepole pine	-1.30E+00 (1.99E-01)	0.000
Demographics		
Age	0.0322 (0.0053)	0.000
Gender	-0.5176 (0.1096)	0.000
Group size	0.0038 (0.0233)	0.869
Income	-9.13E-06 (1.60E-06)	0.000
Travel time to site	-0.0013 (0.0004)	0.001
Total time budget	-0.0081 (0.0016)	0.000
Hypothetical vs. Actual	-0.0004 (0.1553)	0.997
Overdispersion parameter	1.017 (0.045)	0.00
R2	0.162	
Adjusted R2	0.143	
Probability (LR stat)	0.00	
Mean dependent var.	12.98	

Based on the comparison of the restricted and unrestricted log likelihood function, the Likelihood Ratio (LR) statistic is significant at $p < 0.01$ indicating the overall model is significant. The model has an adjusted R^2 value of 0.14 and a Pseudo R^2 of 0.84. The overdispersion parameter is also significant at $p < 0.01$ indicating that overdispersion is present and that the negative binomial count model is appropriate.

The following variables each negatively affected the number of trips taken by individuals and were significant at $p < 0.01$. When lodgepole pine (LP) was present, onsite hikers took an average of 13 trips as opposed to 14 where LP was not present. Bikers took an average of 14 trips in areas with lodgepole present as opposed to 16 without lodgepole. Similarly, increases in respondents' age (AGE), time available for recreation (TTBUD), and income all negatively impacted the number of recreation trips taken to these National Forests in Montana. While the negative relationship between aging and hiking and biking seems intuitive, the negative relationship between demand and total time budget, and demand and income does not. The sites we sampled were relatively easily accessed and did not necessarily require significant time investments. As respondents become more affluent and have more time, they may substitute to higher quality recreation sites by traveling farther or spending more on more expensive recreation activities. Gender (GENDER) was also significant with males taking slightly fewer trips. With respect to recreation activity, bikers take significantly more trips than do hikers. Table 4 shows trip forecasts for significant fire and site related variables.

Variable	Hike trips	Bike trips
Crown fire recovery		
No fire	14.0	15.6
20 years	13.6	15.7
40 years	13.4	15.7
Prescribed fire recovery		
No fire	14.0	15.6
20 years	14.3	15.4
40 years	14.8	15.1
Lodgepole pine		
Not present	14.0	15.6
Present	13.2	13.7
Acres burned		
0	14.0	15.6
10,000	13.5	14.4
100,000	13.1	12.9

Table 4. Fire effects on recreation in Montana

Because we used a count model, we estimate consumer surplus as the inverse of the coefficient on total cost $ß_8$ plus ß9 (total cost and total cost squared are significant at p <0.01.). Consumer surplus per day for hiking demand in Montana is $37/trip. Given a 95% confidence interval, consumer surplus ranges from $24 to 75/trip. With respect to trip value, neither crown fire nor Rx burn had significant effects on consumer surplus.

Fire characteristics did affect visitor demand however; significant fire effects include areas recovering from prescribed fires (FIREAGE), fire size as measured by the number of acres burned, and the areas recovering from crown fires (CROWNFIREAGE) ($p < 0.01$). The average number of trips taken per individual without fire is 14.0 for hikers, and 15.6 for bikers (Table 4). As areas recover from Rx burns over a period of 40 yr, the average number of trips increases for hikers from 14.0 to 14.8. The trips taken in response to fire by bikers were not significantly different from those taken by hikers; the number of trips taken decreases slightly over time from 15.6 to 15.1.

While the coefficient sign for Rx burn was expected, the sign of the coefficient on areas recovering from crown fires was the opposite of what we expected. Given the direct effects of Rx burns on visitation, one would expect similar reactions to areas recovering from crown fires. However, the relationship between demand and the interaction between crown fire and fire age is indirect for hikers. As areas that have been burned by crown fires recover, visitation drops from 14.0 to 13.4 over 40 yr. There was no significant difference between bikers and hikers in terms of response to crown fire and prescribed fire (see Table 4).

Finally, the number of acres burned adversely affected demand for recreation for both hikers and bikers. The negative coefficient for acres indicates that as fires increase in size from zero acres to 100,000 ac, recreation demand will drop from 14.0 to 13.0 trips for hikers and from 15.6 to 12.9 trips for bikers.

CONCLUSION

Results suggest that although demand for hiking and biking is influenced by fire effects, individual net values are not. We therefore cannot reject the null hypotheses that crown fire (TCCROWN) and Rx burns (TCFIREAGE) have no affect on the values per trip of these two recreation activities. Similarly, there are no significant differences between the two user groups with respect to crown fires and prescribed burns (BIKETCCROWN vs. TCCROWN, BIKETCFIREAGE vs. TCFIREAGE). This finding is different from that of Loomis et al. (2001) who show that crown fires and Rx burns influence the values for both groups, although less for bikers. For example, in Loomis et al. (2001), hikers exhibit declining value per trip as areas recover from both crown fires and Rx burns. The opposite was true for bikers. These differences in findings suggest that values vary across states, and that results from other states cannot be generally applied to assess recreation value.

With respect to fire effects, we cannot reject the null hypothesis that crown fires have no effect on hiker and biker demand. For both recreation activities, the coefficient on crown fire was not significant (CROWN, BIKECROWN). This is a surprising result given that areas recovering from crown fires do affect demand: both aging Rx burns (FIREAGE) and aging crown fires (CROWNFIREAGE) had an effect on demand. Therefore, we reject the null hypothesis that FIREAGE and CROWNFIREAGE are equal to zero. Rx burns directly affect hiker demand resulting in increased visitation as areas recover. The coefficient on the bike variable (BIKEFIREAGE) indicated that there was no significant difference between hikers and bikers, although bikers were slightly adversely affected (a decrease of less than one trip per individual). As areas recover from crown fire over time, visitation by hikers decreases slightly. Again, the reverse was true for bikers, although the difference between hikers and bikers was not statistically significant. In each case, the absolute change in demand, although statistically significant, is small enough to be inconsequential from a managerial perspective. A comparison of the results to the findings of Loomis et al. (2001) reveals similar patterns. In Colorado, Wyoming and Montana areas recovering from Rx burns result in increased demand by hikers and decreased demand by bikers. The opposite is true for areas recovering from crown fires.

The percentage of the burn observable from the trail (BURNOBS), and fire size (ACRES) were both statistically significant. Demand for hiking decreases 1% as fire size increases to 1000 acres, 4% as fire reaches 10,000 acres, and 7% as fire increases to 100,000 acres and greater. Biking demand decreases 1% as fire size reaches 1,000 acres, 8% as fire size reaches 10,000 ac and 17% for fires of 100,000 ac and beyond.

As the percentage of burn increased from zero to 50%, hiking demand declined 1.5%, and biking demand declined 4.7%. In both cases, bikers seem to be more sensitive to changes in site characteristics affected by fire. This may be due to downed woody debris and other impediments to bike maneuverability. Because of these differences, fire and recreation planners may want to consider burn size in areas frequented by bikers.

Finally, the presence of lodgepole pine onsite resulted in decreased visitation by both hikers and bikers. The average number of trips taken per individual to sites without lodgepole pine present was 14.0 for hikers, and 15.6 for bikers. When lodgepole pine was present, hikers took 5% fewer trips (13.3) and bikers took 12% fewer trips (13.7). This suggests that recreation users prefer to hike in areas with Douglas-fir, aspen, ponderosa pine, and larch. From a fire management perspective treating lodgepole pine areas with prescribed fire may result in fewer negative impacts to recreation users. Conversely, it could increase recreation demand by reducing the presence of the undesirable species, lodgepole pine.

In general, although respondents in this and the Loomis et al. (2001) study behaved in a similar manner, the degree to which they were affected was dissimilar suggesting that national or regional fire management policies cannot be broadly applied. This is important when considering policymaking and management from a broader than local perspective. Research should be conducted to assess the reason for the difference in demand among states.

Lastly, because the public is becoming more educated in natural resources, particularly with respect to fire through media coverage and local programs and cooperatives, it would be useful to conduct the same survey in the future to test differences in recreation value for hiking and biking over time. While our results may be used to calculate the opportunity costs of prescribed fires, such costs may fall over time with education and increased knowledge. Lastly, it would be useful to compare respondents engaged in other recreation activities to see how they are affected by fire and how their demands and value compare to hikers and bikers.

LITERATURE CITED

Arno, S. F., and J. K. Brown. 1991. Overcoming the paradox in managing wildland fire. West. Wildlands (Spring), 40-46.

Boxall, P. D. Watson, and J. Englin. 1996. Backcountry recreationists' valuation of forest and park management features in the Canadian Shield Region. Can. J. of For. Res. 26: 982-990.

Englin, J., and T. A. Cameron. 1996. Augmenting travel cost models with contingent behavior data. Env. Res. Econ. 7: 133-147.

Englin, J., P. Boxall, K. Chakraborty, and K. Watson. 1996. Valuing the impacts of forest fires on backcountry forest recreation. For. Sci. 42: 450-455.

Flowers, P. J., H. J. Vaux, Jr., P. D. Gardner, and T. J. Mills. 1985. Changes in recreation values after fire in the northern Rocky Mountains. USDA For. Serv. Res. Note Pacific RN-PSW—373.

Loomis, J. B., A. González-Cabán, and J. Englin. 2001. Testing for differential effects of forest fires on hiking and mountain biking demand and benefits. J. of Ag. and Res. Econ. 26(2):508-522.

Loomis, J. B., J. Englin, and A. González-Cabán. 1999. Effects of fire on the economic value of forest recreation in the intermountain west: preliminary results. USDA For. Serv. Gen. Tech. Rep. PSW-GTR-173. p 199-208.

Loomis, J., and R. Walsh. 1997. Recreation Economic Decisions, 2^{nd}, Ed. Venture Publishing, State College, PA, 430 p.

Vaux, H. J. Jr., P. D. Gardner, and T. J. Mills. 1984. Methods for assessing the impact of fire on forest recreation. USDA For. Serv. GTR-PSW-79. 13 p.

US Water Resources Council. 1979. Procedures for Evaluation of National Economic Development (NED): Benefits and Costs of Water Resources Planning (Level C). Final Rule. Federal Register 44(242): 72892-977.

A MULTICULTURAL EVALUATION OF THE PERFORMANCE OF CONTINGENT VALUATION FOR FOREST FIRE PREVENTION

JOHN LOOMIS, ARMANDO GONZÁLEZ-CABÁN & HAYLEY HESSELN

INTRODUCTION

The summers of 2000 and 2002 were two of the worst on record for forest fires in the United States. The summer of 2002 resulted in catastrophic wildfires burning nearly six million acres, destroying more than 2,300 houses, and resulting in 20 firefighter deaths. Damages and restoration costs are in the hundreds of millions of dollars. In response, President Bush proposed a Healthy Forests Initiative for Wildfire Prevention on August 22, 2002. A key element in this initiative is reduction of excess brush and ground fuels that have accumulated due to past fire suppression. This reduction in fuels is to be accomplished by mechanical thinning of the forests and by controlled or prescribed burning of the forest floor.

The policy of accelerating the amount of land to be mechanically thinned or prescribed burned to 2.5 million acres a year is not without opposition. Prescribed burning can generate significant quantities of smoke that affects visibility and creates health problems for people with respiratory conditions. Prior initiatives to increase prescribed burning in states such as Florida have often been limited by citizen opposition due to smoke and health effects. Thus a policy relevant issue is whether this time there will be sufficient public support for an active prescribed burning program to occur. This prescribed burning program is also expensive and costs as much as $250 per acre (Loomis et al. 2002). This paper represents an effort to answer the question of public support and willingness to pay for a prescribed burning program among three different ethnic groups in California. These three ethnic groups include Whites, Hispanics and African Americans.

Collectively, minority groups are close to becoming the majority in many states of the United States. Some of these minority groups speak languages other than English. US Bureau of Census data indicate that 32 million adults in the US speak a language other than English at home. Furthermore, these multiracial populations are increasing faster than the English speaking population in many states. Census data from 1990 to 1999 showed that on average, the Hispanic population grew by 39% in the U.S, with states such as Arizona, California, Florida, and Texas, having an even more rapidly increasing Hispanic population. Many in the Hispanic population either do not speak English or are more fluent in Spanish than in English. In our study area in California, nearly one-third of the population (11 million people) are Hispanic or Latino. Another important racial or ethnic group in California is African American, representing 7.5% of the population or 2.5 million people.

The growing importance of minority groups has been formally recognized in numerous policies, including Executive Order 12898 which requires federal agencies to evaluate environmental justice of federal actions on minority populations. In order to carry out this evaluation, policy makers must understand whether there are any differential effects of their projects or policies on minority cultures. Surveys are commonly used to assess the potential effects of policy actions on residents (Bainbridge 1989).

A guiding assumption of survey methodology has been that similarity between interviewers and respondents influences survey responses (Reese et al. 1986), and that similarity may increase the validity of survey responses (Hurtado 1994). If the validity or accuracy of answers depend on matching racial, ethnic and language characteristics of respondents and interviews, surveys become more expensive and cumbersome. The effect of race on answers to general surveys has been a topic of general survey research interest for decades (Lenski and Leggett 1960). Differences in responses to racial or sensitive survey questions have been traced to differences between the race of the respondent and that of the interviewer in in-person interviews (Schuman and Converse 1971). What little research on differences due to ethnicity or language indicates few ethnic or language differences in responses to factual or demographic questions (Weeks and Moore 1981). There is less testing of racial/ethnic interviewer effects in phone interviews (Cotter et al. 1982). Effects of ethnicity and language on survey response rates appear not to be systematically researched (e.g., there is no mention of this topic in Dillman's recent (2000) book for example and database searches show no entries). We suspect there would also be response rate differences to mail and phone surveys due to race and ethnicity as well. Besides any obvious language difficulties, many minority cultures often feel marginalized by the dominant public institutions such as government agencies and universities. As such they tend to have low voter participation. It is plausible that the same disinterest may carry over to answering referendum contingent valuation surveys, particularly if sponsored by the dominant culture's institutions like government or universities.

Performing surveys in multiple languages for multiple cultures is also a difficult task. To increase within culture accuracy and response rates the survey instrument may need to be fairly culturally specific. Yet doing so reduces its functional equivalency across groups, making group comparisons or aggregation of results more difficult (Tindigarukayo 2001).

Given the difficulties of making surveys culturally context specific, yet maintaining sufficient consistency for aggregation, coupled with the costs of training interviewers in different languages, it is not surprising that nearly all CVM surveys have been in English. Those not able to speak, read or write proficiently in English have either been purposely omitted in the sample design as ineligible or the individuals themselves simply chose not to respond. This is not just a problem in CVM. In the recreation literature, we are aware of very few surveys conducted in Spanish, even in California (Chavez 2002). Whether explicit omission of non-English speakers or implicitly through language selection effects, this potentially leads to unrepresentative samples that limit generalizability of empirical results or, more commonly, an underestimate of benefits by omitting benefits received by non-English speaking households. To date, no studies have compared CVM responses of Whites, African American, and Hispanic households. We might expect differences in responses across cultures to arise at any one of several stages in a CVM analysis. First, there may be differences in survey response rates. Second, differences may result at each design point in a CVM survey: (1) a scenario description of the problem; (2) one or more proposed solutions; (3) an associated mechanism to pay for the solution. The same words, even in the same language, may have different meanings to Whites from African Americans and Hispanics. All of these subtleties can lead to differences in interpretation of the CVM scenarios and differences in WTP.

When differences in language and associated translation are introduced, the potential for respondents to arrive at a different interpretation may increase. In some cases there may not even be equivalent words. Furthermore, no matter how realistic the payment mechanism may be, different racial and ethnic groups may view the effectiveness of government agencies to deliver the program quite differently and this can lead to protest responses. Cultures that are in the minority may have a well-founded distrust of government. Yet, as the US becomes a more multi-cultural society, these issues become increasingly important to policy makers who often want to know how different segments of society benefit from different environmental policies and public programs. This may be especially true of many environmental programs that can have different effects across racial and ethnic lines.

The objective of this study was to determine if differences exist in survey response rates, overall WTP question protest responses, particular reasons given for refusing to pay, and differences in WTP estimates for White households, African American households, and Spanish-speaking households (half of whom took the survey in Spanish). The program under study is quite relevant to people living in California, as it is a wildfire fuels reduction program via prescribed burning. The unique feature of this experimental design of having half the Hispanics take the survey in English and half in Spanish will aid in understanding how a respondent's native language may shape their participation and response in CVM surveys. If cultural differences are found, it may suggest the need to tailor material in the CVM survey so as to better communicate culturally. This research will enable us to evaluate how well traditional non-market valuation methods such as CVM work with different racial and ethnic groups.

HYPOTHESES: RESPONSE RATE & PROTEST RESPONSES

Our survey modes involve an initial random digit dialing phone call with a short (five minutes) initial interview. We then request name and address to mail a survey booklet and schedule time for an in-depth (20 minute) interview. Thus, the first basis of comparison is whether African Americans, Hispanics and Whites respond equally to the initial phone call and follow through on the in-depth interview. Since the interviewers identified themselves as being with a California university, it is hypothesized that these three groups might react differently to a request from a university. Therefore they may not be equally responsive to the request for an initial interview, or a follow-up in-depth interview. Such a differential response rate would make it more difficult to generalize results from a survey sample to the population. The null hypothesis is that the overall survey response rate (R) to the CVM survey is independent of language and ethnicity:

$$Ho: R_{AfricanAmericans} = R_{Hispanic\text{-}spanish} = R_{Hispanic\text{-}english} = R_{white}$$

This will be tested using a four by two contingency table and a χ^2 test.

Responses to the in-depth interview are the main focus of our analysis. First, we compare the groups' reasons for refusing to pay anything. Some refusals are valid expressions of zero WTP since they reflect lack of value for the good or low income (i.e., inability to pay). Other respondents who give a zero valuation or refusal to pay because they reject the scenario or rationale that citizens should have to pay for this program, are often termed protest responses (Mitchell and Carson 1989, Halstead et al. 1982). These respondents often do not "buy into" the premise that they are responsible for paying for the solution, or are unconvinced the solution will actually work, or feel government will not spend the money collected on the specific program. Here too, cultural differences between the majority culture and a minority culture may result in systematically different responses, with higher protest responses from a more distrusting minority culture.

To determine what might potentially be a protest response the following strategy was used. First, if a respondent indicated he or she would vote against the program at their initial bid amount, they were asked whether they would pay $1. If they said they would not pay $1, they were asked an open-ended question "Why did you vote this way?" The interviewer was instructed to type in exactly what the respondent said. After all interviews were completed, the reasons were analyzed for content to classify answers by similar reasons given by the respondent. This open-ended response approach avoids having respondents fit themselves into pre-set protest categories or having the interviewer place them into pre-set categories.

Comparing the overall protest reasons given, we will test the null hypothesis of no difference between the four groups in terms of acceptance of the premise and credibility of the CVM survey. The null hypothesis is that the distribution of refusals to pay and protest responses to the CVM survey are independent of ethnicity and language:

$$Ho: Protest_{AfricanAmericans} = Protest_{Hispanic-english} = Protest_{Hispanic-spanish} = Protest_{White}$$

This will be tested using a four by two contingency table. Significance tests will be performed using a χ^2 test.

WTP Model and Related Hypothesis Tests

As suggested by the NOAA panel on contingent valuation, a voter referendum willingness to pay question format was used (Arrow et al. 1993). Hanemann (1984) and Cameron (1988) both provide motivations for how a respondent may answer a dichotomous choice CVM question. Hanemann views the respondent as evaluating the utility difference associated with the current program level versus paying some amount ($X) for an increase in the program level. If the utility difference is positive for the program, the individual is believed to respond "Yes". If the utility difference is distributed logistically, a logit model can be used to estimate the parameters and allow for calculation of WTP. The effect of language and ethnicity will be tested for using a logit model in two primary ways. First, we can test whether ethnicity and language simply shifts the logit function up or down by an intercept shifter (e.g., $ß_2$, $ß_4$, $ß_6$) or affects the bid slope of the logit function (e.g., $ß_3$, $ß_5$, $ß_7$) in equation (1):

$$ln(P_i/1-P_i) = ß_0 + ß_1 Bid + ß_2\, AfricanAmericans + ß_3\, Bid*(AfricanAmericans) + ß_4\, Hispanic\text{-}Spanish + ß_5\, Bid*(Hispanic\text{-}Spanish) + ß_6\, Hispanic\text{-}English + ß_7\, Bid*(Hispanic\text{-}English) + ..ß_n X_n + u_i \quad [1]$$

where: Bid is the dollar amount the respondent is asked to pay; AfricanAmericans is one for African Americans, and zero for whites and Hispanics; Hispanic-Spanish is one for Hispanics taking the survey in Spanish; Hispanic-English is one for Hispanics taking the survey in English.

The null hypotheses are:

$Ho: ß_2 = 0; Ho: ß_3 = 0; Ho: ß_4 = 0; \ Ho: ß_5 = 0; Ho: ß_6 = 0; \ Ho: ß_7 = 0$

The hypotheses are tested through evaluation of the t-statistic on the respective coefficients.

A more general test is to evaluate whether *all* the coefficients in the logit equation would vary with ethnicity and language. Thus, four separate logit equations are estimated, one each for Whites (W), AfricanAmericans (AA), Hispanic-Spanish (HS) and Hispanic-English (HE) of the form:

$$ln(P_i/1-P_i) = W_0 + W_1\, Bid + W_2\, X_2 + W_3\, X_3 + ... + W_n X_n + u_i \quad [2a]$$

$$ln(P_i/1-P_i) = AA_0 + AA_1\, Bid + AA_2\, X_2 + AA_3\, X_3 + ... + AA_n X_n + \varepsilon_I \quad [2b]$$

$$ln(P_i/1-P_i) = HS_0 + HS_1 Bid + HS_2 X_2 + HS_3 X_3 + ... + HS_n X_n + \gamma_I \quad [2c]$$

$$ln(P_i/1-P_i) = HE_0 + HE_1 Bid + HE_2 X_2 + HE_3 X_3 + \ldots + HE_n X_n + \phi_I \quad [2d]$$

The null hypothesis is of coefficient equality across all four groups:

$Ho: W_0 = AA_0 = HS_0 = HEg_0;\ W_1 = AA_1 = HS_1 = HE_1; \ldots W_n = AA_n = HS_n = HE_n$

The null hypothesis is tested using a likelihood ratio test comparing the separate logit equations to a pooled logit equation of all four groups. The results are determined through evaluation of the χ^2 statistic. If this null hypothesis is rejected, then it is sensible to investigate which ethnicity and language treatments are the ones that are statistically different from each other, and which, if any, are not statistically different from each other. Thus, we will conduct a series of pairwise tests if needed.

Comparisons of mean WTP estimates across ethnicity and language groups will be used to establish whether differences exist in benefits of the public programs. The null hypothesis states that WTP estimate by ethnicity and language are not different:

$$Ho: WTP_{White} = WTP_{Hispanic\text{-}English} = WTP_{Hispanic\text{-}Spanish} = WTP_{AfricanAmericans}$$

The results are determined by whether the confidence intervals overlap.

SURVEY DESIGN

The survey booklet was developed in conjunction with forestry professionals in California see Appendix C). It described the acreage that is burned by wildfires in an average year as well as the typical number of houses lost to wildfire each year. Next, a program increasing the use of prescribed fire or controlled burning in California was described. Specifically, respondents were told that the prescribed burning fuels reduction program would reduce potential wildfire fuels through periodic controlled burning. It was acknowledged that prescribed burning does create some smoke, although far less than a wildfire. Then the survey booklet provided additional information and drawings contrasting wildfire and prescribed fire. The cost of financing this program of prescribed burning was described as a cost-share program between the State of California and the county the individual lived in.

The WTP elicitation wording was:

> *" California is considering using some state revenue as matching funds to help counties finance fire prevention programs. If a majority of residents vote to pay the county share of this program, the Expanded California Prescribed Burning program would be implemented in your county on federal state, and private forest and rangelands. Funding the Program would require that all users of California's forest and rangelands pay the additional costs of this program. ...If the Program was undertaken it is expected to reduce the number of acres of wildfires from the current average of 362,000 acres each year to about 272,500 acres, for a 25% reduction. The number of houses destroyed by wildfires is expected to be reduced from an average of 30 a year to about 12. Your share of the Expanded California Prescribed Burning program would cost your household $__ a year. If the Expanded Prescribed Burning Program were on the next ballot would you vote*
>
> *__In favor ___Against?*

The basic format of the survey booklet and script had previously been through six focus groups in two different states (including the Spanish language version), so it was necessary to pretest the booklet and script on only the four ethnic subgroups in English and Spanish prior to beginning survey administration.

Data Collection and Survey Mode

The survey was conducted through a phone-mail-phone process. To obtain a representative sample of households, random digit dialing of the households living in a sample of California counties was performed. The counties were selected so there was a mix of counties that frequently experience wildfires, counties that occasionally experience wildfires, and counties that almost never experience wildfires. Once initial contact was established, language was verified along with elicitation of initial attitude and knowledge of wild and prescribed fire, followed by the scheduling of appointments with individuals for detailed follow-up interviews. During the interim time period, a color survey booklet was mailed to the household. Interviews were conducted with the aid of this color booklet, which was sent in English to Whites, African Americans and approximately one half of the Hispanic households. The other half of the Hispanic households received the survey in Spanish. Individuals were asked to read the survey booklet prior to the phone interview. Phone interviews were conducted in either English or Spanish depending on the language of the booklet.

RESULTS

Comparison of Survey Response Rates

Because the survey was conducted in two waves, we compare the ethnic groups on response rates from the initial random digit dial phone survey and the follow-up, in-depth interviews separately in Table 1. The response rates to the initial phone calls were all over 40%, but there was a statistically significant difference between the four groups in response to the initial phone call. The highest response rate (75.5%) was by Hispanics phoned by a Spanish speaking interviewer. Thus, the additional effort to contact people in their native language certainly paid off during the initial interview. In particular, we obtained a significantly higher response rate (based on the chi-square statistic of 9.98) by conducting the initial interview with Hispanics in Spanish as compared to English. Unfortunately, the opposite effect occurs in the in-depth interviews. Upon mailing a Spanish language booklet to Hispanic households, we obtained a relatively low response rate of 33% in this phase; significantly lower than obtained from Hispanics who were sent the survey booklet in English. This is a somewhat puzzling result since we would have expected that the prospect of being called back by a Spanish language interviewer would have resulted in a higher response rate on the in-depth interview phase. On the flip side, the response rate of Whites was the highest in the in-depth interviews. Overall, there is a statistically significant difference in response rates to the initial phone interview across the four samples (chi-square = 58.61) and the in-depth phone interview (chi-square 34.25). However, in the in-depth interviews, Whites have a statistically higher response rate than African Americans, while in the initial interviews they were not different.

Table 1. Response Rates by Ethnic Group and Language with Chi-Square Tests

		African Am.	Hispanics (English)	Hispanics (Spanish)	Whites	Total
First Wave-Screener						
Total Initial Sample Contacted		708	733	620	794	2855
Completed Intial		308	421	468	328	1525
1st Wave Resp Rate		43.5%	57.4%	75.5%	41.3%	53.4%
Chi-Square Total						58.61***
Chi-Sq	African Am. vs Whites	0.298				
Chi-Sq	Hispanic in English vs Hispanics in Spanish		9.98***			

Second Wave -In-Depth Interview		African Am.	Hispanics (English)	Hispanics (Spanish)	Whites	Total
Refused to give address		4	9	1	4	18
Phone disc, moved, not avail		25	37	47	16	125
Not called by end		3	0	0	51	54
Net Sample for 2nd		276	375	420	257	1328
Completed		126	170	139	187	622
2nd Wave Resp Rate		45.7%	45.3%	33.1%	72.8%	46.8%
Chi-Square Total						34.25***
Chi-Sq	African Am. vs Whites	10.51***				
Chi-Sq	Hispanic in English vs Hispanics in Spanish		5.48**			

** indicates significant at the 5% level. *** indicates significant at the 1% level.

Reasons Why Households Would Not Pay for the Program

Table 2 presents the analysis of refusals to pay, i.e., individuals that indicated they were in favor of the prescribed burning program at no cost, but then would neither pay their initial bid amount nor pay the follow-up $1 willingness to pay question. These individuals appear to favor the program but essentially have a zero WTP. Table 2 lists the reasons why a person would not pay the $1. The first three reasons listed in Table 2 are *not* considered protest responses because having no value for the program or receiving no benefits from the program, as well as not being able to afford to pay, are valid reasons for zero WTP. However, the other three categories are considered protests because they were frequently prefaced with, “I am in favor of program” or “I'm all for it but think the program should be paid for by those living in the forests or with existing taxes.”

Because of the frequency of zero cell entries for some ethnic groups for specific protest responses, only an overall chi-square of protest responses versus non-protest responses could be computed. The calculated chi-square of 1.994 indicates no statistically significant difference among the ethnic groups in the pattern of protest and non-protest reasons for refusing to pay. Nonetheless, it is noteworthy that no refusals to pay were received from Hispanic households being interviewed in Spanish. Across all four groups there is substantial overall support for prescribed burning as a means to reduce wildfire. Specifically, there were only 23 households out of 622 households (3.7%) that would not pay $1, and only 12 of these were considered protest responses.

Table 2. Why Respondents Would Not Pay $1

Reason	African Americans	Hispanics (English)	Hispanics (Spanish)	Whites	Total
No Value/No Benefits	0	3	0	1	4
Cannot Afford	1	1	0	3	5
Taxes Already too High	0	0	0	2	2
Should be Paid for with Existing Taxes	2	0	0	4	6
Those that Live in Forest Should Pay	1	0	0	0	1
Other	1	3	0	1	5
Total	5	7	0	11	23

Results of Logit Regressions

Table 3 presents the results of the "full" logit model that includes not only the ethnicity and language variables, but also other demographics (Income, Gender, Home Value), attitudes (prescribed burning causes health problems-HealthProblems), and whether they have witnessed a fire (WitnessFire) and/or observed neighbors' houses burning (NeighborBurn). These other non-ethnicity variables were included to attempt to control for as many of these factors as possible to guard against our hypothesis tests of ethnicity and language being influenced by omitted variable bias. Overall, the coefficient on the bid amount (Bid) is negative and statistically significant at the 0.01 level, as is whether respondents view prescribed burning to cause health problems from smoke (significant at the 0.05 level).

In terms of our hypotheses regarding ethnicity and language, Table 3 indicates that none of these ethnicity or language logit intercept shift variables or logit bid slope interaction terms are statistically significant at conventional levels. Specifically, the Hispanic-Spanish (HS) and Hispanic-English (HE) intercept shifters were not statistically different from zero. Neither were the respective bid slope interaction terms (HSBid and HEBid). Neither of the African American intercept shifter nor bid slope interaction (AABid) variables were statistically different from zero.

Table 3 Logit Function With Ethnicity Intercept and Bid Slope Interactions

Variable	Coefficient	t-Statistic	Probability
Constant	2.2873	5.086	0.000
Bid	-0.0051	-3.514	0.000
Health Problems	-0.6689	-2.136	0.032
Witness Fire	0.1272	0.469	0.638
Neighbor Burn	0.4139	0.847	0.396
Home Value	4.42E-07	0.857	0.391
Income	-4.05E-06	-1.182	0.236
Gender	-0.3479	-1.413	0.157
HispanicSpanish (HS)	0.5903	0.948	0.342
HSBID	0.0031	1.252	0.210
HispanicEnglish (HE)	-0.0639	-0.128	0.897
HEBID	0.0029	1.439	0.149
African Am (AA).	-0.0927	-0.179	0.857
AABID	0.0012	0.569	0.568
Mean dependent var	0.8032	Log likelihood	-225.498
S.E. of regression	0.387	Restr. Log likelihood	-244.464
Sample Size	493	Probability (LR Statistic)	0.00029

The results in Table 3 suggest that differences in ethnicity cannot be accounted for solely by a simple intercept shifter and bid slope. Thus, the differences might be more pervasive, involving differences in all the coefficients. Therefore, the same model specification as in Table 3 was estimated for each of the four groups individually, without the ethnicity and language variables (logit regression results are available from the lead author). Finally, the likelihood ratio tests are reported in Table 4.

As is evident in the third column of Table 4, the likelihood ratio test of coefficient equality of all four groups is rejected at the 5% level (calculated chi-square is 40.84 while the critical is 32.67). Therefore, we conducted pairwise likelihood ratio tests to determine which ethnic groups and language treatments are different. The fourth column indicates that we should reject equality of coefficients for survey treatments comparing Hispanics who received the survey in English versus Spanish at the 5% level (calculated chi-square was 14.92 while the critical is 14.06). Coefficient equality is also rejected for comparing Whites versus the Hispanics receiving surveys in English and in Spanish (calculated chi-square is 35.78 while critical is 23.68). Similarly, comparing African Americans to the two Hispanic groups results in rejection of coefficient equality at the 5% level (calculated chi-square of 24.22 versus critical of 23.68). However, there is no statistical difference in logit coefficients between Whites and African Americans, as the calculated chi-square is 8.34 while the critical is 14.067. Thus, the differences in logit slope coefficients appear to arise from differences within the Hispanic groups by survey language treatment, and between Whites/African Americans and Hispanics.

Table 4 - Likelihood Ratio Tests of Coefficient Equality Across Ethnic Groups

		All Groups	Hispanics: Spanish vs . English	White vs & Span.	AA vs Hispanic Eng &Sp	White vs AA
Groups	Log Likelihood					
White	70.72					
Black	50.31					
Hispanic-English	61.69					
HispanicSpanish	28.51					
Sum of Unrestricted		211.23	90.2	160.92	140.51	121.03
Pooled-Restricted		231.65	97.66	178.81	152.62	125.2
Calculated Chi-Sq		40.84	14.92	35.78	24.22	8.34
Critical Chi Sq @5%		32.67	14.067	23.68	23.68	14.067
Significantly Different?		Yes	Yes	Yes	Yes	No

Comparison of Mean WTP

Table 5 presents the logit regression equations used to compute mean WTP and the confidence intervals. A reduced form logit equation specification that considered only variables that were statistically significant in at least one of the four sub-groups was used. Variables that were consistently insignificant across all four groups were not included to reduce the variance of the logit equations, and therefore, increase the precision of the confidence intervals. The increased precision is desirable to better test for differences in mean WTP across the two groups. Unnecessarily large variances will reduce our ability to detect whether there is any difference in mean WTP.

Table 5 Logit Regressions Used to Calculate WTP

	Whites			African Americans			Hispanics-English			Hispanics-Spanish		
Variable	Coef.	T-stats	Prob.	Coef.	T-Stats	Prob.	Coef.	T-Stats	Prob.	Coef.	T-Stats	Prob
Constant	2.2293	4.227	0.000	2.3840	3.844	0.000	2.3144	4.576	0.000	4.5108	3.934	0.00
Bid	-0.0054	-3.699	0.000	-0.0040	-2.438	0.014	-0.0013	-0.909	0.363	-0.0018	-0.786	0.43
RX Health Problem	-0.5518	-0.659	0.509	0.1731	0.270	0.786	-0.1348	-0.220	0.826	-2.9375	-2.737	0.00
Income	0.0000	1.137	0.255	0.0000	-1.562	0.118	0.0000	-1.834	0.066	0.0000	-0.755	0.45
Gender	-0.9394	-2.155	0.031	0.0072	0.014	0.989	-0.0008	-0.002	0.998	0.5081	0.798	0.42
Mean dependent	0.7533			0.7670			0.8231			0.8772		
Log likelihood	-73.55			-52.88			-66.40			-34.29		
Restr. Log likelihood	-83.79			-55.91			-68.59			-42.46		
LR statistic	20.48			6.05			4.373			16.33		
Probability (LR stat)	0.0004			0.194			0.357			0.0026		
McFadden R2	0.1222			0.0542			0.0319			0.192		
Sample Size	150			103			147			114		

As can be seen in Table 5, the bid slope coefficients are statistically different from zero at conventional levels (0.01) for Whites and African Americans but not for either Hispanic group. It is encouraging that the sign is negative on bid in both Hispanic regressions, but it is unusual for bid not to be significant in dichotomous choice CVM responses. This is contrary to what Loomis et al. (2002) found for Hispanics living in Florida for a prescribed burning program there. One difference may be that Hispanics in Florida are predominantly from the Caribbean area, while Hispanics in California are from Mexico and Central America. Therefore, future research should investigate such differences.

Mean WTP is computed in Table 6 for the two groups in which the bid coefficient was statistically significant (e.g., African Americans and Whites).

Table 6 Mean WTP and 90% Confidence Intervals

	Mean	**90% Confidence Interval**
Whites	$406	$318-$618
African Americans	$512	$336-$1140

The confidence intervals were calculated using the Park et al. (1991)approach which involves an adaptation of the Krinsky-Robb method to dichotomous choice CVM. Since the 90% confidence interval of Whites overlap the mean WTP of African Americans and vice versa, there is no statistical difference between the mean WTP by Whites of $406 per year and African Americans at $512 per year. As judged by the relative tightness of the confidence intervals for Whites, there appears to be less variance in their WTP than for African Americans. Nonetheless, the mean WTP is a sizable amount per White and African American household, suggesting that a prescribed burning program to effectuate a 25% reduction in acres of forests burned by wildfire, and a 50% reduction in the number of houses destroyed by wildfire is quite valuable to these California households.

CONCLUSIONS

This paper investigated whether the contingent valuation method could effectively be used to evaluate the economic effects of forest fire management policies on different ethnic groups in California. We found a statistical difference in survey response rates between African Americans, Whites and Hispanics. Using Hispanics' native language (Spanish) did improve the response rate to the initial interviews, but this did not carry over to the follow-up, in-depth interview involving the survey booklet. Reasons for not being willing to pay even one dollar for the prescribed burning program were similar among African Americans, Whites, and Hispanics taking the survey in English and Spanish. A logit regression that pooled all respondents and simply controlled for ethnicity and language using an intercept shifter variable and bid slope interaction term did not indicate any statistical differences between the four groups. However, a series of likelihood ratio tests suggest that the slope coefficients in the logit equations were different between Hispanics taking the survey in Spanish and English as well as these two groups and Whites and African Americans. The likelihood ratio test found no statistical difference in logit coefficients between Whites and African Americans. Hispanics had an insignificant coefficient on the bid, a finding robust to whether the survey was administered in English or Spanish. In contrast, Whites and African Americans had a negative and statistically significant coefficient on bid amount. This may suggest that Hispanics were not taking serious the dollar amount they were asked to pay, as a negative and significant sign on the bid amount is one of the few regularities in published dichotomous choice CVM surveys. This finding of insignificance on the bid amount for Hispanics in California contrasts with the finding of significance on the bid amount among Hispanics in Florida (Loomis et al. 2002). It is possible the differences in findings relates to Florida Hispanics tending to be of Caribbean descent while California Hispanics are more frequently of Mexican and Central American descent. This is an interesting area of future research to determine if these cultural distinctions are the source of the difference in these findings.

Overall, the dichotomous choice contingent valuation method appears well suited for evaluating economic effects on African Americans and Whites in California, but perhaps less well suited for evaluating the economic effects on Hispanics in California. Of course this conclusion would benefit from replication with different public policies to see if our results are specific to forest fire prevention programs or robust to the type of public good offered.

With regard to President Bush's Healthy Forest Initiative, forest fire prevention using prescribed burning does appear to have substantial support across all four sampled ethnic groups in California. Only 4% of the sample would not pay at least $1 for the program. The mean willingness to pay of Whites and African Americans is substantial at $405 and $512. Even if non-respondents have zero willingness to pay, $400 per household over five million paying households would be sufficient to cover the costs in California.

REFERENCES

Arrow, K., R. Solow, P. Portney, E. Leamer, R. Radner and H. Schuman. 1993. Report of the NOAA Panel on Contingent Valuation. US Department of Commerce, Federal Register 58(10): 4602-4614.

Cameron, T. 1988. A New Paradigm for Valuing Non-Market Goods Using Referendum Data." *Journal of Environmental Economics and Management* 15(4): 355-79

Chavez, Deborah. 2002. Adaptive Management in Outdoor Recreation: Serving Hispanics in Southern California. *Western Journal of Applied Forestry* 17(3): 129-133.

Halstead, J., Luloff, A., and Stevens, T. 1982. Protest Bidders in Contingent Valuation. *Northeastern Journal of Agricultural and Resource Economics* 21. p 160-169.

Hanemman, M. 1984. Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses." *American Journal of Agricultural Economics* 67(3): 332-341

Loomis, John, Lucas Bair and Armando Gonzalez-Caban. 2002. Language Related Differences in a Contingent Valuation Study: English Versus Spanish. *American Journal of Agricultural Economics.* Forthcoming, December 2002.

Loomis, John, D. Griffin, E. Wu and A. Gonzalez-Caban. 2002. Estimating the Economic Value of Big Game Habitat Production from Prescribed Fire using a Time Series Approach. *Journal of Forest Economics* 8: 119-129.

Mitchell, R., and Carson, R. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Ed. Washington D.C.: Resources for the Future.

Park, T., Loomis, J., and Creel, M. 1991. Confidence Intervals for Evaluating Benefit Estimates from Dichotomous Choice Contingent Valuation Studies." *Land Economics* 67(1): 64-73.

Turner, C., Rogers, S., Hendershot, T., Miller, H., and Thornberry, J. 1996. Improving Representation of Linguistic Minorities in Health Surveys. *Public Health Reports* 111(May/June): 276-279.

DO NATIVE AMERICANS RESPOND DIFFERENTLY FROM THE GENERAL POPULATION TO THE CONTINGENT VALUATION METHOD?

ARMANDO GONZÁLAZ-CABÁN, ANDREA RODRIGUEZ, JOHN LOOMIS & HAYLEY HESSELN

INTRODUCTION

Native American communities in the United States have not partaken of the economic boom sustained by the country for over the last 100 years. Like many other minority groups, the impact of government programs on Native American communities has not been studied in depth. In 1994, pressured in part by the social justice movement, President Clinton enacted Executive Order 12898 requiring federal agencies to evaluate the social justice of federal actions on minority populations. The Order requires policy makers to understand the impacts of their projects and policies on different cultural groups and to make sure that these groups do not shoulder the burden of possible negative impacts of proposed programs or actions. Agencies generally use surveys to ascertain the potential impact of their actions on households. However, Loomis et al. (2002) found that past surveys and nearly all contingent valuation method (CVM) studies in the US excluded non-English speakers. They suggested that this could potentially lead to unrepresentative samples that would underestimate aggregate benefits by omitting those benefits received by non-English speaking households. The same is most likely true of Native American communities as little effort has been made to survey these populations.

To date there have been no published comparisons between Native American and non-Native American CVM responses. Differences in responses across cultures might be expected at any one of several stages of a CVM design: (1) a scenario description of the problem, (2) one or more proposed solutions, and (3) an associated payment vehicle for the solution. Even though focus groups and pretests are used to reduce scenario rejection and increase the believability of the payment mechanism, different cultural backgrounds can lead to different interpretations of the CVM scenarios and therefore affect willingness-to-pay (WTP). This is particularly true if there are significant differences in the environmental ethic of the groups being compared.

Regardless of the realism of the payment vehicle used, different cultures may view government agencies' effectiveness in providing the program differently, leading to protest responses. Sometimes the payment vehicle may not be applicable to some groups. Minority cultures may also have a well-founded distrust of government. The history of broken promises and failed treaties between Native Americans and the US Government would certainly contribute to this distrust. In addition, there may be cultural differences with respect to our particular natural resource program, prescribed burning. Specifically, Native Americans had a historic tradition of using prescribed burning to maintain favorable conditions for game animals (Pyne 1982). In light of Executive Order 12898, the relevancy of these issues to policy makers and natural resource managers is heightened because of the need to know how different segments of society benefit from different environmental policies and public programs.

The objective of this study was to determine the level of support by Native American communities in Montana compared to Montana's general population for two alternative wildland fire mitigation strategies. In addition we wanted to test how well the CVM works in

Native American communities with regard to the applicability of the method and how well it captures Native Americans' WTP for nonmarket products and/or services. This research may help policy makers and natural resource managers understand how respondents' cultures influence participation and response. Differences in willingness to pay between Native Americans in Montana and members of Montana's general population may suggest the need to add culturally-specific material to future CVM surveys.

METHODS

Contingent Valuation Method

The contingent valuation method (CVM) uses survey techniques to elicit values for nonmarket goods or services. CVM uses stated preferences by respondents based on a contingent market for the good or service evaluated. This elicitation process is necessary because there is a lack of observable market forces for services such as wildland fire risk reduction. CVM enables the calculation of willingness to pay for the good or service, as well as the estimation of benefits.

Although there are still concerns about the reliability and validity of its results (see Carson et al. 1996, Diamond and Hausman 1994), empirical test-retest studies have demonstrated CVM results to be reliable (Loomis 1989 1990; Reiling et al. 1990). CVM is an accepted tool to obtain values for a nonmarket good or service. For example, the Water Resource Council recommends federal agencies such as the Army Corps of Engineers and the Bureau of Reclamation to use CVM (US Water Resource Council 1983). The Department of Interior has recommended its use for valuing natural resource damages (US Department of Interior 1986, 1994). In addition its use has been upheld in Federal Court (US District Court of Appeals 1989). A "blue ribbon panel" co-chaired by two Nobel laureates has also recommended CVM (Arrow et al. 1993) for measuring passive use values. CVM has seen increasing use in valuing wildfire prevention, including Fried et al. (1999) and Loomis et al. (2002).

Dichotomous Choice CVM

The blue ribbon panel also recommended that CVM surveys be conducted using a dichotomous choice format such as a voter referendum. This asks the individual whether they would vote in favor or against a preset bid amount that varies across the sample.

Cameron and James (1987) view the respondent as comparing this amount they are asked to pay to their personal maximum willingness to pay. They answer Yes if the bid amount is less than their personal maximum WTP and No if the amount is greater than their WTP. However, the individual's WTP is unobservable to the researcher, all that is known is the respondent's Yes or No response to the bid amount. Cameron's valuation approach, which is now referred to as a variation function due to its link to WTP measures such as compensating or equivalent variation (McConnell 1990), attempts to estimate this unobserved WTP using a probit model (Cameron and James 1987).

SURVEY DESIGN

Program Valued

The principal source of information for development of the survey instrument used in Montana was USDA Forest Service wildland fire management personnel at the regional (USDA Forest Service Northern Region, R1) and local levels. Personnel provided technical information on how the prescribed burning and mechanical fuels reduction projects are conducted and the possible environmental effects associated with each activity. They also reviewed the survey instrument to assure the correct representation of the wildland urban interface problem in Montana. This was particularly important because the origin of the survey instrument used in this study was designed for a project in Florida evaluating the response of different ethnic groups to three wildland fire reduction strategies (Loomis et al. 2002, Loomis et al. 2001).

Samples from Montana's general population and Native American population both received the following information for valuing the expanded prescribed burning program.

> *"Montana is considering using some state revenue as matching funds to help federal, state, tribal and private individuals finance fire prevention programs. If a majority of residents vote to pay the county share of this program, the Expanded Montana Prescribed Burning Program would be implemented in your county and other counties in Montana on federal, state, tribal and private forest and rangelands.*
>
> *Funding of the Expanded Montana Prescribed Burning Program would require that all users of Montana's forest and rangelands, such as timber companies, recreation visitors, and Montana households pay the additional cost of this program. If this Expanded Prescribed Burning Program were to be implemented, by law, the money would be deposited in a separate Montana Prescribed Burning Fund, which could only be used to carry out the Expanded Prescribed Burning Program described above. A citizen advisory board would review the expenditures from the fund annually.*
>
> *If the Expanded Prescribed Burning Program was undertaken it is expected to reduce the number of acres of wildfires from the current average of approximately 140,000 acres each year to about 105,000 acres, for a 25% reduction. The number of houses destroyed by wildfires is expected to be reduced from an average of 20 a year to about 8.*
>
> *Your share of the Expanded Montana Prescribed Burning Program would cost your household $__________ a year. If the Expanded Montana Prescribed Burning Program were on the next ballot would you vote?*
>
> *___In favor __Against"*
>
> *The $___ was filled in with one of 10 different dollar amounts ranging from $10 to $470."*

When asked to value a mechanical fire fuels reduction program both sample populations were presented the following information.

> *"Another approach to reducing the build up of fuels in the forest is to "mow" or mechanically chip the low and medium height trees and bushes into mulch. This is especially effective at lowering the height of the vegetation, which reduces the ability of fire to climb from the ground to the top or crown of the trees. In addition, mechanical "mowing" slows the new vegetation growth with the layer of mulch acting as a barrier.*
>
> *Mowing or mulching 50,000 acres of forest and rangelands is more expensive than prescribed burning, due to increased labor and equipment needs. It would also decrease the number of ground cover plant species reducing food for wildlife. However, unlike prescribed burning, mulching does not produce any fire smoke."*
>
> *If the Mechanical Fire Fuels reduction Program was undertaken instead of the Expanded Prescribed Burning Program, it is expected to reduce the number of acres*

of wildfires from the current average of approximately 140,000 acres each year to about 105,000 acres, for a 25% reduction. The number of houses destroyed by wildfires is expected to be reduced from an average of 20 a year to about 8.

Your share of this Mechanical Fire Fuels reduction Program would cost your household $__________ a year. If the Mechanical Fire Fuels reduction program was the <u>*ONLY*</u> *program on the next ballot would you vote?*

_________In favor   _________Against"

The amount per year was filled in with one of 10 different dollar amounts ranging from $15 to $480.

Focus Groups

The revised and adapted survey instrument was tested in two focus groups conducted in February of 2001 to improve the comprehensibility to the Native American populations. The focus groups were conducted one each on the Confederated Salish-Kootenai reservation, Pablo, MT, and the Blackfeet reservation, Browning, MT. Both focus groups consisted of about 18 to 20 people. There was no problem in the interpretation or comprehension of the information provided on the survey instrument. Following the focus groups a complete mail booklet and survey script was developed. Because the same survey was being used for Montana's general population and the original was pretested in Florida we felt there was no need to conduct another pretest with Montana's general population. The final survey was an 8-page color booklet (see Appendix C).

The willingness to pay question used a voter referendum format. The payment vehicle was an increase in state income taxes for the program. In order to begin to assess whether refusals to pay were protest responses, any respondent that indicated they would not pay their initial bid amount was asked a follow-up question at $1 cost. Those who said no to $1 were asked an open-ended question as to why they voted no. These responses were recorded verbatim by the interviewer and then post-coded by the author who conducted the focus groups into protest and non-protest refusals to pay.

Sample Design

The final target sample size to achieve our desired objectives was 500 completed interviews. The data collection was divided into two groups: i) Native Americans and ii) Montana's general population. The Native Americans were further divided into two groups: (a) the Confederated Salish-Kootenai Tribe and (b) the Blackfeet Tribe. The target sample size for each of the two tribes was 125 completed interviews for a total of 250 Native American households. The target sample for Montana's general population was also 250 households. The final sample size was 499 completed interviews, short by 23 interviews with Native Americans and high by 22 interviews with general Montana residents. These data are listed in Table 1.

Table 1. Survey response rate comparisons.

	Montana general		Native Americans			
			Blackfeet		Salish-Kootenai	
	Total	Pct.	Total	Pct.	Total	Pct.
First wave						
Total initial sample	602		329		325	
Completed initial survey	406	67.4	243	73.9	240	73.8
			?2 = 6.2301 (p = 0.05)			
Second wave						
Phone disconnect, moved, deceased, not available	25		24		9	
Not called by end of study	0		4		14	
Net second wave sample	381		215		217	
Completed second survey	272	71.4	102	47.4	125	57.6
	?2 = 33.2097 (p = 0.001)					

Survey Mode

Random digit dialing was used to obtain a representative sample[1]. Together with the interviewer screening protocol, in which the interviewer asked to speak with a person in the household who is 18 or older and has the next birthday, random digit dialing should result in a sample balanced by gender. Concerned about the possibility of the lack of phone availability in households on tribal lands we discussed the issue with tribal officials for both tribes. We were assured that nearly all tribal members had phones.

The initial contact was used to secure participation from the household and to agree to an appointment for a detailed follow-up interview using a typeset, color booklet that would be mailed to them. The booklet contained questions and scenarios about the two different fire management policies (prescribed burning and mechanical fuel treatment), in addition to two figures contrasting wildland fires and prescribed fires. Participants were asked to read the booklet prior to the agreed upon phone interview. The interviews were conducted in English to obtain demographic information and answers regarding support for each fire management policy described in the scenarios.

RESULTS AND DISCUSSION

Montana general population residents and Native American residents were surveyed starting in spring of 2001 and continuing until spring 2002. The final dataset was received for analysis in April 2002. The initial response rate to the screening protocol for Montana's general population was 67.4 percent, and 73.9 and 73.8 percent, respectively for the Blackfeet and the Confederated Salish-Kootenai tribes (first wave; table 1). A chi-square test showed significant differences at the 0.05 level between the three populations' response rates for the screening protocol.

Individuals who were not interviewed because of an incorrect phone number or not having appropriate respondent qualifications, such as being under 18, were not included in the final calculated response rate. Those participants who refused to complete the interview or rescheduled without future contact (callback) were included in the response rate as unit non-responses. Likewise, any individual contacted but not interviewed was included in the

[1] The use of random digit dialing guarantees that nearly all households are eligible for interview. This is especially important because of unlisted phone numbers. This problem causes difficulties in contacting these households by mail because they will not appear on commercially available mailing lists.

response rate as non-response. The unit non-response category also included respondents who completed the screener but did not follow through with completion of the entire survey process. Taking all these factors into account produced a net sample size for the second interview of 381 individuals for Montana's general population, and 215 and 217 for the Blackfeet and the Confederated Salish–Kootenai tribes respectively. The final response rates for Montana's general population, the Blackfeet tribe and the Confederated Salish-Kootenai tribe were 71.4, 47.4, and 57.6 percent respectively. A chi-square test showed that the response rates of the net sample for these three populations are significantly different from each other at the 0.001 level (second wave; table 1).

Table 2. Protest response rate comparisons.

	Fuel treatment program			
	Prescribed burning		Mechanical fuels reduction	
	Montana general	Native American	Montana general	Native American
Protest responses	24	14	86	48
Non-protest responses	189	176	174	171
Percent protest	11.3	7.4	33.1	21.9
?^{2} p value	0.1812		0.0067	

The differences between the sum of the first two rows in table 2 and the final row in table 1 is due to some cases missing values for independent variables used in the models. For example, 272 residents from Montana's general population completed the survey, but 59 of them had missing values for one or more of the independent variables used in the prescribed burning model. Twelve of them had missing data for the independent variables used in the mechanical fuels reduction model. The same explanation holds true for the Native American sample.

One possible explanation for the lower response rate of Native Americans could be that they avoided answering the survey if they opposed the program. People familiar with the behavior of Native Americans suggest that their way of avoiding saying no or disagreeing is to abstain. Another possible explanation is that their treatment of time commitments is different from the general population. That is, they might not view time appointments as binding as those from other cultures.

Analysis of Protest Responses

The interviewer recorded open-ended statements of the reason why any respondent voted no to paying the stepped down minimum bid of $1. A "no" response for reasons other than lack of value for the program or inability to afford it constituted a protest vote. The most often cited protest responses for the prescribed burning program were "someone else should pay" (31.6% of protest responses), "I don't trust the state and/or federal government" (10.5%), and "opposed to new taxes" (7.9%). Protests to the mechanical fuels reduction program included "ecologically damaging" (14.2%), "prescribed burning is better" (13.4%), and "the program will not work" and "log it first" (9.0% each). "No" responses were tabulated and identified as protests or non-protests for each fuel treatment program for both groups of interest. Both Native Americans and members of Montana's general population had higher rates of protest for the mechanical fuels reduction program.

To test whether there is a difference in protest rates for general Montana households and Native Americans, protest responses were aggregated to a contingency table (table 2). Protest rates for the prescribed burning program were 7.4 percent for Native Americans and 11.3 percent for Montana residents. A chi-square test indicates there is no statistical difference between these protest rates ($p = 0.1812$). Protest rates for the mechanical fuels reduction program were much higher for both groups at 21.9 percent for Native Americans and 33.1 percent for Montana residents. Furthermore, the protest rate for Montana general residents is significantly higher than for Native Americans (p = 0.0067).

Statistical Analysis of WTP Responses

The survey information was used to estimate a probit regression for estimation of the WTP for the two fuel treatment methods. Use of the probit regression to calculate the WTP for Native Americans and Montana's general population allows for the valuation of each fuel treatment program and the introduction of income, tribe and other demographic factors, and how they influence the support for the evaluated programs, and to correct for sample selection bias.

Bivariate Probit Regression

Many dichotomous choice CVM data have been typically analyzed with the logit model, partly because the underlying logistic distribution allows for more convenient estimation compared to other binary choice models (Greene 2000). This does not mean, however, that the logit is the only model to use for CVM. The probit, a binary choice model based on the standard normal distribution, can also be applied to CVM data. Once the probit coefficients are estimated the Hanemann's (1984, 1989) formula for median WTP is applicable to the probit model as well.

One extension of the probit model is the bivariate probit with sample selection[2]. This model incorporates Heckman's (1979) thoughts on sample selection bias into the standard bivariate probit, a model with two simultaneously estimated equations that allows for correlation between the error terms in each equation. The premise of Heckman's sample selection model is that "using non-randomly selected samples to estimate behavioral relationships" results in biased and inconsistent parameter estimates (1979, p. 153). Because self-selected respondents may differ in some significant way from non-respondents, it is important to correct for this bias. Ignoring this issue could lead to inconsistent parameter and WTP estimates, making them unfit for generalization to the population.

Following Boyes et al. (1989) and Greene (2000), the bivariate probit with sample selection model consists of two equations simultaneously estimated with maximum likelihood: one for the binary choice of whether to pay the corresponding bid amount for the fire mitigation program (y_{i1}), and another for the binary choice to participate in the follow-up interview (y_{i2}). Because binary choice outcomes are considered reflections of underlying regressions (Greene 2000), we let * denote a latent variable and assume that y_{i1}^* and y_{i2}^* follow

$$\begin{aligned} y_{i1}^* &= X_{i1}b_1 + e_{i1} \\ y_{i2}^* &= X_{i2}b_2 + e_{i2} \end{aligned} \qquad [1$$

for $i = 1, 2, \ldots, N$, where X_{ij}, $j = 1, 2$, are $N \times k_j$ matrices of independent variables, $ß_j$ are $k_j \times 1$ vectors of coefficients to be estimated, and e_{ij} are disturbances distributed bivariate normal with zero mean, unit variance and correlation coefficient *?*. The variable y_{i1} takes on a value of 1 if the respondent is willing to pay and 0 if not:

[2] It was first introduced by van de Ven and van Praag (1981), and has since been used extensively in the loan default and credit scoring literature (see Boyes et al. 1989, Greene 1992, Jacobson and Roszbach 2003).

$$y_{1i} = \begin{cases} 1 & \text{if willing to pay } \left(y_{i1}^{*} > 0 \right), \\ 0 & \text{if not } \left(y_{i1}^{*} \leq 0 \right), \end{cases} \quad [2]$$

and the variable y_{i2} takes on a value of 1 if the respondent participated in the follow-up interview and 0 if not:

$$y_{2i} = \begin{cases} 1 \text{ if participated in follow-up interview } \left(y_{i2}^{*} > 0 \right), \\ 0 \text{ if not } \left(y_{i2}^{*} \leq 0 \right). \end{cases} \quad [3]$$

Keeping in mind that y_{i1} is observed only if y_{i2} = 1, parameter estimates are obtained by maximizing the following log-likelihood function:

$$\ell = \sum_{i=1}^{N} y_{i1} y_{i2} \ln \Phi_2 \left[X_{i1} b_1, X_{i2} b_2, r \right] + \sum_{i=1}^{N} (1 - y_{i1}) y_{i2} \ln \Phi_2 \left[- X_{i1} b_1, X_{i2} b_2, r \right] + \sum_{i=1}^{N} (1 - y_{i2}) \ln \Phi \left[- X_{i2} b_2 \right], \quad [4]$$

where $\Phi_2[\cdot]$ and $\Phi[\cdot]$ represent the bivariate and univariate standard normal cumulative distribution functions. Simultaneous estimation allows for correlation between the two equations, resulting in parameter estimates that are more efficient than those obtained from estimating the two equations separately. In addition, possible sample selection bias is corrected for, meaning that parameter estimates derived from the bivariate probit with sample selection are generalizable to the population of interest (Boyes et al. 1989) assuming that the first stage of the probit model reflects a random sample of the population. We believe this to be the case since we used random digit dialing for the initial phone calls and obtained fairly high initial call response rates (67%-74%).

Initial development of the probit regression begins with determining assumed significant variables that influence support or valuation as listed in Table 3.

Table 3. Variable names and definitions.

Variable	Definition
- - - - - - - - - - -Variables used in WTP equations -	
BidMec	Bid amount for the mechanical fuels reduction program
BidRx	Bid amount for the prescribed burning program
BthrBoth	Dummy where 1 = smoke from wildfire/prescribed burn bothered them physically and visually, 0 otherwise
BthrPhys	Dummy where 1 = smoke from wildfire/prescribed burn bothered them physically, 0 otherwise
BthrVisu	Dummy where 1 = smoke from wildfire/prescribed burn bothered them visually, 0 otherwise
Camp	Dummy where 1 = been hiking, camping, fishing or hunting in past 12 months, 0 otherwise
ConOrg	Dummy where 1 = member of a conservation or environmental organization, 0 otherwise
EvacHome	Dummy where 1 = have evacuated their home due to wildfire, 0 otherwise
Firefigh	Dummy where 1 = been involved in fighting a fire, 0 otherwise
Gender	Dummy where 1 = male, 0 = female
Income	Annual household income of respondent ($1000s)

IntrctMc	Interaction variable, BidMec*MTGenPop
IntrctRx	Interaction variable, BidRx*MTGenPop
MTGenPop	Dummy where 1 = Montana general population, 0 = Native American
NeighBur	Dummy where 1 = neighbor's home burned due to wildfire, 0 otherwise
OwnHome	Dummy where 1 = own current residence, 0 otherwise
RespProb	Dummy where 1 = suffer from respiratory or breathing problems, 0 otherwise
Retired	Dummy where 1 = retired, 0 = not retired
RxDanger	Dummy where 1 = prescribed burning is too dangerous to be used, 0 otherwise
RxHealth	Dummy where 1 = prescribed burning should not be used because of the potential health problems from smoke, 0 otherwise
RxRedHi	Dummy where 1 = prescribed burning reduces the chance of high intensity wildfire, 0 otherwise
VoteMcPr	Dependent dummy where 1 = willing to pay for mechanical fuels reduction program, 0 otherwise
VoteRxPr	Dependent dummy where 1 = willing to pay for prescribed burning program, 0 otherwise
Witness	Dummy where 1 = been in or witnessed a wildfire, 0 otherwise
YrsinMT	Number of years respondent has lived in Montana
- - - - - - - - - - -***Variables used in sample selection equation*** -	
Age	Age of respondent in years
AnmlDead	Dummy where 1 = forest fires result in the death of the majority of animals in the area, 0 otherwise
CmpFinal	Dependent dummy where 1 = completed follow-up survey, 0 otherwise
Educ	Ordinal where 1 = less than high school, 2 = high school graduate, 3 = some college, 4 = bachelor's degree, 5 = advanced degree
FiresOut	Dummy where 1 = all fires, regardless of origin, should be put out as soon as possible, 0 otherwise
HeardRx	Dummy where 1 = read or heard about the use of prescribed burns or prescribed fires, 0 otherwise
MTGenPop	Dummy where 1 = Montana general population, 0 = Native American
NumberHH	Number of people in respondent's household
RxAttrac	Dummy where 1 = periodic use of prescribed burning would make the area more attractive for recreation, 0 = less attractive
RxDamage	Dummy where 1 = if wildfire occurred in an area that had previously been prescribed burned, damage to houses and mature trees would be reduced, 0 otherwise
Sex	Dummy where 1 = male, 0 = female
ShouldRx	Dummy where 1 = forest managers should periodically prescribe burn underbrush and debris in pine forest, 0 otherwise
SRxDangr	Dummy where 1 = prescribed burning is too dangerous to be used, 0 otherwise
SRxHealt	Dummy where 1 = prescribed burning should not be used because of the potential health problems from smoke, 0 otherwise
SRxRedFl	Dummy where 1 = prescribed burning effectively reduces the amount of excess fuels in the forest, 0 otherwise
SRxRedHi	Dummy where 1 = prescribed burning reduces the chance of high intensity wildfire, 0 otherwise

Probit Regression Results

The first test to determine if the general population of Montana has a different WTP function than Native Americans living in Montana was whether these two groups differ only by an intercept shifter and bid slope interaction term. A statistically significant bid slope interaction term would potentially indicate a significant difference in WTP, because the bid slope has a direct influence on WTP. To be as general as possible we include all the variables that theory or the past literature suggests may be important determinants of WTP. Regression results showed that Montana's general populations intercept (MtGenPop) and bid slope interaction variables (IntrctRx) were not significantly different from zero for either the prescribed burning program or the mechanical fuels reduction program. The t-stats on MtGenPop and IntrctRx were insignificant, as was the likelihood ratio test statistic ($c_2^2 = 0.988$) testing the joint significance of the two variables together. This suggests there are no simple differences between these two groups with respect to these programs.

Prescribed Burning Program Probit Models

The bivariate probit with sample selection model corrects parameter estimates for sample selection bias; thus, these are the parameter estimates that should be used to estimate WTP[3].

The correlation parameter Rho is 0.828 and is significant at the 0.01 level indicating that sample selection bias is present. This means that respondents to the second wave (in-depth interview) are in some way systematically different from non-respondents, and more importantly, this difference plays a role in how people respond to the willingness to pay question. In particular, second wave respondents are more likely to be older, Montana general population residents, and less likely to believe that prescribed burning (RX burning) is too dangerous to be used. Comparing the single equation and bivariate models through a likelihood ratio test shows that the bivariate model is a better fit – the likelihood ratio test statistic $c_1^2 = 6.158$ is significant at the 0.05 level.

Table 4. Median WTP estimates from the reduced prescribed burning and mechanical fuels reduction programs bivariate probit model.

Model	Median WTP	Confidence intervals 95%	Confidence intervals 90%
Prescribed Burning	Program		
Means1	$154.89	($816.90) - $511.81	($414.92) - $430.26
Reduced2	$65.18	($1,398.40) - $381.93	($698.43) - $333.28
RxDanger3	($920.13)	($7,413.40) - ($210.09)	($4,118.40) - ($299.81)
EvacHome4	$814.95	$28.68 - $4,209.70	$164.26 - $2,633.90
Retired5	$554.01	$54.55 - $2,332.90	$159.45 - $1,584.00
Mechanical Reduction	Program		
Means6	$295.19	($55.55) - $844.12	$10.98 - $689.81
Reduced2	$41.13	($714.42) - $801.36	($544.36) - $639.21
EvacHome4	$504.93	($224.50) -$1,707.50	($106.97) -$1,387.20

The dollar amount asked of each respondent to fund the program (BidRx) follows economic theory. The higher the dollar amount asked of each respondent, the less likely they are to vote in favor of the program. BidRx is negative and significant at the 0.10 level. RxDanger is negative and significant at the 0.10 level, indicating that those who believe prescribed burning is too dangerous to be used are less likely to vote in favor of the Prescribed Burning program. EvacHome is positive and significant at the 0.10 level, indicating that people who have evacuated their home due to fire are more likely to vote in favor of the prescribed burning program. This makes sense, as these people have experienced the impact of fire before, and might be more likely to vote in favor of any fire mitigation program. Retired is positive and significant at the 0.05 level, indicating that people who are retired are more likely than people who aren't retired to vote in favor of the Prescribed Burning program. A possible explanation for this could be that retired people are, by and large, living on a fixed budget and would support any program that would decrease the risk of a large fire that could burn their homes; therefore, reducing the possibility of incurring any economic losses as a result of wildfires.

[3] Note, full results are available from the principal investigator.

Reduced Prescribed Burning Program Probit Models for WTP Estimates

Having estimated the initial model with all the variables thought to be relevant, these preliminary probit regressions were used to determine the significant variables affecting the WTP for each fuel treatment program for each of the two sample groups: Native Americans and Montana's general population. A reduced model containing only significant variables was used to calculate median and mean WTP figures and confidence intervals around them. Results for only the regressions without the protest responses are reported below. A reduced model including only the significant variables was run to reduce standard errors (Greene 2000, p. 338) (table 4).

Table 4. Median WTP estimates from the reduced prescribed burning and mechanical fuels reduction programs bivariate probit model.

Model	Median WTP	Confidence intervals	
		95%	90%
Prescribed Burning Program			
Means[1]	$154.89	($816.90) - $511.81	($414.92) - $430.26
Reduced[2]	$65.18	($1,398.40) - $381.93	($698.43) - $333.28
RxDanger[3]	($920.13)	($7,413.40) - ($210.09)	($4,118.40) - ($299.81)
EvacHome[4]	$814.95	$28.68 - $4,209.70	$164.26 - $2,633.90
Retired[5]	$554.01	$54.55 - $2,332.90	$159.45 - $1,584.00
Mechanical Reduction Program			
Means[6]	$295.19	($55.55) - $844.12	$10.98 - $689.81
Reduced[2]	$41.13	($714.42) - $801.36	($544.36) - $639.21
EvacHome[4]	$504.93	($224.50) -$1,707.50	($106.97) -$1,387.20

[1] Evaluated at sample means presented in table 4.
[2] All dummy values are zero.
[3] Dummy for RxDanger = 1, others zero.
[4] Dummy for EvacHome = 1, others zero.
[5] Dummy for Retired = 1, others zero.
[6] Evaluated at sample means presented in table 6.
Combinations (i.e. EvacHome and Retired, EvacHome and OwnHome, etc.) would be redundant, as their frequency in the sample is small.

Rho is significant at the 0.01 level, indicating that sample selection bias is present. Like the full model, this means that respondents to the second wave (in-depth interview) are in some way systematically different from non-respondents, and this difference plays a role in how people respond to the willingness to pay question. In particular, second wave respondents are more likely to be older, Montana general population residents, less likely to believe that prescribed burning is too dangerous to be used, and more likely to believe that R_X burning effectively reduces the amount of excess fuels in the forest. Comparing the single equation and bivariate models through a likelihood ratio test shows that the bivariate model is a better fit – the likelihood ratio test statistic $c_1^2 = 5.233$ is significant at the 0.05 level.

As stated earlier the bivariate probit with sample selection model corrects parameter estimates for sample selection bias; thus, these are the parameter estimates to be used to estimate WTP. Like in the full model the sign on the coefficient on dollar amount asked of each respondent to fund the program (BidRx) follows economic theory. The higher the dollar amount asked of each respondent, the less likely they are to vote in favor of the program. BidRx is negative and significant at the 0.05 level. RxDanger is negative and significant at the 0.01 level, indicating that those who believe prescribed burning is too dangerous to be used are less likely to vote in favor of the prescribed burning program. EvacHome is positive and significant at the 0.05 level, indicating that people who have evacuated their home due to fire are more likely to vote in favor of the prescribed burning program. This makes sense, because they have experienced fire. Retired is positive and significant at the 0.01 level (table 5), indicating that people who are retired are more likely to vote in favor of the prescribed burning program. As in the full model, a possible explanation for this could be that retired people are, by and large, living on a fixed budget and would support any program that would decrease the risk of a large fire that could burn their homes; thereby reducing the possibility of incurring economic losses as a result of wildfire.

Again, a separate model was run including a population intercept variable (MtGenPop) and bid interaction term (IntrctRx) to determine whether Native Americans and Montana general population residents were different. The model results show that the two populations are not statistically different. The t-stats on MtGenPop and IntrctRx were insignificant, as was the likelihood ratio test statistic ($c_2^2 = 1.047$) testing the joint significance of the two variables together.

WTP for the prescribed fuel treatment program was calculated from the probit bivariate model.[4] The median WTP for the prescribed burning program, estimated at the sample means of the variables included in the reduced bivariate model, is $155 (table 5). When all dummy variables are set to equal zero, median WTP is $65. This value is pertinent because while RxDanger, EvacHome and Retired are indeed significant, 74.4% of the respondents included in the reduced model have zero values for each of these variables.

Mechanical Fuels Reduction Program Probit Models

The bivariate probit with sample selection model corrects parameter estimates for any sample selection bias that might be present; thus, these are the parameter estimates that should be used to estimate WTP . Unlike the prescribed burning case, the parameter Rho is not significant, indicating that sample selection bias is not present in the mechanical fuels reduction program. This indicates that differences between the first and second wave do not play a role in how people respond to the willingness to pay question. Second wave respondents are more likely to be older, Montana general population residents, and more likely to have heard of prescribed burning prior to survey. Comparing the single equation and bivariate models through a likelihood ratio test shows that there is no statistically significant difference – the likelihood ratio test statistic $c_1^2 = 0.1328$ is not significant.

While there is no statistically significant difference between the bivariate and single equation models, the bivariate model will be used because it is more efficiently estimated (simultaneously estimated; the log-likelihood is larger). The sign on the coefficient on dollar amount asked of each respondent to fund the program (BidMec) follows economic theory. The higher the dollar amount asked of each respondent, the less likely they are to vote in favor of the program. BidMec is negative and significant at the 0.01 level as indicated in Table 5.

Table 5. Median WTP estimates from the reduced mechanical fuels reduction program bivariate probit model.

Model	**Median WTP**	**Confidence intervals**	
		95%	90%
Means	$295.19	($55.55) - $844.12	$10.98 - $689.81
Reduced	$41.13	($714.42) - $801.36	($544.36) - $639.21
EvacHome	$504.93	($224.50) -$1,707.50	($106.97) -$1,387.20

[4] Complete results are available from the principal investigator.

RxRedHi is positive and significant at the 0.05 level, indicating that those who believe prescribed burning effectively reduces the probability of future high intensity wildfires are more likely to vote in favor of the mechanical fuels reduction program. This finding is puzzling. Although a possible interpretation could be that people who think that prescribed burning reduces the probability of future high intensity wildfires may also think that maintenance of the area after the prescribed burning could be achieved effectively through mechanical reduction of the new fuels. EvacHome is positive and significant at the 0.05 level, indicating that people who have evacuated their home due to fire are more likely to vote in favor of the mechanical fuels program. OwnHome is negative and significant at the 0.10 level, indicating that respondents who own their homes are less likely to vote in favor of a mechanical fuels reduction program. This too is puzzling, but a plausible explanation could be that homeowners do not want all the noise and exhaust from the heavy machinery associated with mechanical fuels reduction or they may value the privacy that a dense stand of trees provides. Income is positive and significant at the 0.05 level, indicating that people with higher income are more willing to pay for mechanical fuels treatments. This makes sense, as mechanical fuels reduction is a relatively expensive fire mitigation strategy.

A separate model was run including a population intercept variable (MtGenPop) and bid interaction term (IntrctMc) to determine whether Native Americans and Montana general population residents are different. Model results show that the two groups are not significantly different. The t-stats on MtGenPop and IntrctMc were insignificant, as was the likelihood ratio test statistic ($c_2^2 = 2.600$) testing the joint significance of the two variables together.

Mechanical Fuels Reduction Program Reduced Probit Models for WTP Estimates

A reduced model including only the significant variables was run to reduce the standard errors of those variables (Greene 2000, p. 338). Table 6 include median WTP estimates for the reduced fuels treatment programs.

Table 6. Median WTP estimates from the reduced prescribed burning and mechanical fuel

Model	**Median WTP[1]**	**Confidence intervals 95%**	**90%**
Prescribed Burning Program			
Montana general population[2]	$174.38	($711.33) - $559.04	($396.38) - $457.58
Native Americans[3]	$134.94	($801.93) - $498.38	($483.53) - $408.30
Mechanical Reduction Program			
Montana general population[4]	$286.17	($65.16) - $773.80	$1.73 - $668.24
Native Americans[5]	$305.50	($57.84) - $837.49	$13.26 - $684.88

1 Evaluated at sample means.

2 N = 160; mean of RxDanger = 0.02500; mean of EvacHome = 0.05625; mean of Retired = 0.18750.

3 N = 149; mean of RxDanger = 0.06040; mean of EvacHome = 0.08054; mean of Retired = 0.14094.

4 N = 137; mean of RxRedHi = 0.93431; mean of EvacHome = 0.03650; mean of OwnHome = 0.80292; mean of Income = 43.99270.

5 N = 140; mean of RxRedHi = 0.95000; mean of EvacHome = 0.08571; mean of OwnHome = 0.75000; mean of Income = 38.19643.

The correlation parameter Rho is not significant, indicating that sample selection bias is not present. This indicates that any differences between the first and second wave responses do not play a role in how people respond to the willingness to pay question.

Second wave respondents are more likely to be older, Montana general population residents, and more likely to have heard of prescribed burning prior to survey. Comparing the single equation and bivariate models through a likelihood ratio test shows that there is no statistically significant difference. The likelihood ratio test statistic $c_1^2 = 0.1464$ is not significant.

While there is no statistically significant difference between the bivariate and single equation models, the bivariate model is used because it is more efficiently estimated. As in the full model, the sign on the coefficient on dollar amount asked of each respondent to fund the program (BidMec) follows economic theory. The higher the dollar amount asked of each respondent, the less likely they are to vote in favor of the program. BidMec is negative and significant at the 0.01 level. EvacHome is positive and significant at the 0.05 level, indicating that people who have evacuated their home due to fire are more likely to vote in favor of the mechanical fuels reduction program.

A separate model including a population intercept variable (MtGenPop) and bid interaction term (IntrctMc) was run to determine whether Native Americans and Montana general population residents are different. As in the previous cases model results show that the two groups are not different. The t-stats on MtGenPop and IntrctMc were insignificant, as was the likelihood ratio test statistic ($c_2^2 = 1.890$) testing the joint significance of the two variables together.

WTP for the mechanical fuels reduction treatment program was calculated from the probit bivariate model. Median WTP for the mechanical fuels reduction program, estimated at the sample means of the variables included in the reduced bivariate model, is $295. Calculating reduced median WTP where all dummy variable equal zero does not make sense for the mechanical program, as the occurrence of all variables equaling zero is very small. Median WTP evaluated for each statistically significant dummy variable with its value set to one and the others set to zero help to illustrate the effects of each variable on WTP. For example, median WTP forEvacHome = 1 is 505.

Comparison of Willingness to Pay between Native Americans and MT households

For both the prescribed burning and the mechanical fuels reduction program there are no statistical differences between Native Americans' mean WTP and general Montana residents. It is interesting to note that in contrast to Loomis et al. (2002), that here the Native Americans have a much greater variance of WTP than general Montana residents.

Mean WTP is calculated using the coefficients from the reduced bivariate probit regression models and the means of the independent variables. Because we are splitting the sample into two sub-samples for comparison, the means of the independent variables for each sub-sample are different. Therefore, differences between Native Americans' WTP and Montana general population residents' WTP are due only to differences in the sample means of the independent variables included in the regression models.

Computed from the reduced model excluding protest responses, the Native Americans' mean WTP for prescribed burning is $135, and the Montana general population residents' mean WTP is $174. In contrast, Native Americans have a higher WTP for the mechanical fuels reduction program than Montana general population residents. The Native Americans' mean WTP for mechanical fuels reduction is $306, and for the Montana general population residents' mean WTP is $286.

CONCLUSIONS

Responses of Montana residents and members of two tribes, living on and off of Reservations in Montana were compared on survey response rates, protest responses and willingness to pay for two forest fire prevention programs. A combination phone interview with respondent followed by a mailed information booklet was used to convey the prescribed burning and mechanical fuels reduction program. The comparison indicates the survey response rates for Native Americans and other Montana residents were statistically different at the 0.05 level for the initial contact phone interview, and at a 0.001 level for the follow-up, in-depth interviews. Protest responses for the prescribed burning program were not a statistically different at 7.4% for Native Americans and 11.3% for Montana residents. The protest rate for the mechanical fuels reduction program was much higher for both groups at 21.9% for Native Americans and 33.1% for Montana residents and the difference is significant at the 0.01 level. This result suggests that different information may be needed to convey the mechanical fuels reduction program, such as using a different name for the program (timber thinning), or using a different payment vehicle for the more reluctant general residents of Montana.

Results from bivariate probit with sample selection models indicate that there is no statistically significant difference between the Native American and Montana general population's willingness-to-pay for either program.

Although the participation rates of both groups in the survey were statistically significantly different, we found no statistical significant differences in their protest rates of the two fuels reduction treatment programs. This leads us to believe that in general the contingent valuation survey for natural resources programs worked reasonably well for Native Americans living on and off the Reservations in Montana. The biggest difference was in follow-up survey response rates. Native Americans had a significantly lower response rate that would have reduced the ability to generalize from the sample of Native Americans to their population. However, by using a bivariate probit with sample selection bias model the WTP estimates can be generalized. Nonetheless, future surveys should attempt to see if monetary incentives or other means of motivating Native Americans, like a letter from Tribal Council, might improve response rates. In terms of support for the forest fire management programs, support for prescribed burning was similar between general Montana households and Native Americans. For the mechanical fuels reduction program, the significantly lower protest rate indicates Native Americans actually supported this program at a higher level than did Montana residents. In terms of WTP, we found that Native American households were willing to pay a higher amount to implement the mechanical fuel treatment programs than Montana general population households, but that these amounts are not statistically different for the two groups. Native American households' WTP for prescribed burning is less than Montana residents, but again the differences are not statistically significant.

REFERENCES

Arrow, K., R Solow, P. Portney, R. Leamer, R. Radner, and H. Schuman. 1993. Report of the NOOA Panel on contingent valuation. Federal Register 58(10): 4602-4614.

Boyes, W.J., D.L Hoffman, and S.A. Low. 1989. An econometric analysis of the bank credit scoring problem. Journal of Econometrics 40: 3-14.

Cameron, T. and M. James. 1987. Efficient Estimation Methods for "Closed-Ended" Contingent Valuation Surveys. Review of Economics and Statistics. 69: 269-275.

Carson. R., N. Flores, K. Martin, and J. Wright. 1996. Contingent Valuation and Revealed Preference Methodologies: Comparing Estimates for Quasi-Public Goods. Land Economics 72(1): 80-99.

Diamond, P., and J. Hausman. 1994. Contingent valuation: Is some number better than no number? Journal Economic Perspective 8(4): 45-64.

Fried, J., G. Winter and J. Gilless. 1999. Assessing the benefits of reducing wildfire risk in the wildland urban interface: A contingent valuation approach. International Journal of Wildland Fire 9(1): 9-20.

Greene, W.H. 1992. A statistical model for credit scoring. Working Paper No. EC-92-29, Department of Economics, Stern School of Business, New York University.

Greene, W.H. 2000. Econometric analysis, 4th ed. Upper Saddle River, NJ: Prentice Hall; 1004 p.

Haab, T. and K. McConnell. 2002. Valuing environmental and natural resources: The econometrics of non-market valuation. Edward Elgar, Northampton, MA.

Hanemann, M. 1984. Welfare evaluations in contingent valuation experiments with discrete responses. American Journal of Agricultural Economics 66(3): 332-341.

Hanemann, M. 1989. Welfare evaluations in contingent valuation experiments with discrete response data: reply. American Journal of Agricultural Economics 71(4): 1057-1061.

Heckman, J. 1979. Sample selection bias as a specification error. Econometrica 47(1): 153-161.

McConnell, K. 1990. Models for Referendum Data: The Structure of Discrete Choice Models for Contingent Valuation. Journal of Environmental Economics and Management 18(1): 19-34.

Mitchell, R., and R. Carson. 1989. Using surveys to value public goods: The contingent valuation method. Washington, DC: Resources for the Future; 463 p.

Loomis, J. 1989. Test-retest reliability of the contingent valuation method: A comparison of general population and visitor responses. American Journal of Agricultural Economics 71: 76-84.

Loomis, J. 1990. Comparative reliability of the dichotomous choice and open-ended contingent valuation techniques. Journal of Environmental Economics and Management 18: 78-85.

Loomis, J.B., L.S. Bair, and A. González-Cabán. 2001. Prescribed fire and public support: knowledge gained, attitudes changed in Florida. Journal of Forestry 99(11): 18-22

Loomis, J.B., L.S. Bair, and A. González-Cabán. 2002. Language related differences in a contingent valuation study: English versus Spanish. American Journal of Agricultural Economics 84(4): 1091-1102.

Park, T., J. Loomis,, and M. Creel, 1991. Confidence intervals for evaluating benefit estimates from dichotomous choice contingent valuation studies. Land Economics 67: 64-73.

Pyne, S. 1982. Fire in America: a cultural history of wildland and rural fire. Princeton University Press, Princeton, NJ. 654 p.

Jacobson, T. and K. Roszbach. 2003. Bank lending policy, credit scoring and value at risk. *Journal of Banking & Finance*,. 27(4): 615-633

Reiling, S., K. Boyle, M. Philips,and M. Anderson. 1990. Temporal reliability of contingent values. Land Economics 66(2): 128-134.

US Department of the Interior. 1986. Natural resource damage assessments; Final Rule. Federal Register 51. Washington, DC.

US Department of the Interior. 1994. Natural resource damage assessments; Final Rule. Federal Register 59(58): 14262-14287.

US District Court of Appeals (for the District of Columbia). 1989. State of Ohio vs. US Department of Interior. Case No. 86-1575. July 14, 1989.

US Water Resources Council. 1983. Economic and environmental principles for water and related land resources implementations studies. Washington, DC.

van de Ven, W.P.M.M., and B.M.S. van Praag. 1981. The demand for deductibles in private health insurance: a probit model with sample selection. Journal of Econometrics 17: 229-252.

ECOLOGICAL ANALYSIS

Our third objective was to assess ecosystem effects in response to treatment type. Information was derived using a GIS and consultation with ecological and fire management personnel in the federal agencies. Ecological effects were measured according to condition class and departure from mean fire return interval. Ecological results can then be coordinated with cost information to assess treatment efficiency in the long run.

A MODELING APPROACH TO ANALYZING ECOLOGICAL CONDITION AS A RESULT OF ALTERNATIVE FUELS TREATMENT STRATEGIES

DONALD HELMBRECHT & HAYLEY HESSELN

INTRODUCTION

Wildland fire plays an important role in many forested ecosystems by means of its influence on vegetative composition and structure, landscape patterns, and ecological functioning (Brown and Smith 2000). In the Northern Rocky Mountains, many of these ecosystems and their associated species are considered to be fire-adapted, meaning that they have the ability to survive and regenerate in a fire-prone environment. Historically, fire has maintained the characteristics that define these ecosystems. Land managers and researchers have begun to acknowledge that many of the past century's land management policies and practices, especially fire exclusion, have led to major changes in how fire influences fire-adapted forest ecosystems.

In the absence of fire, forest succession leads to the replacement of fire-resistant tree species with less fire-resistant species and subsequent increases in density and fuel loading. These changes are most apparent within short-interval, fire-adapted systems, which historically experienced frequent, low intensity fire events, but have also occurred in ecosystems that historically experienced less frequent, high intensity events (Brown and Smith 2000). Over time, this transformation has directly affected the natural fire regime (Morgan et al. 1996, Barrett 2002, Hardy et al. 2001) resulting in uncharacteristic fire frequency, severity, and/or spatial extent. By using the historical fire regime as a reference condition, the natural variability concept provides a framework within which to evaluate the impacts of altered fire regimes and the consequences of future management actions (Landres et al. 1999).

Current wildland fire management acknowledges the importance of restoring the natural ecological role of fire: the 2001 Federal Wildland Fire Management Policy states as a guiding principle that "The role of wildland fire as an essential ecological process and natural change agent will be incorporated into the planning process" (US Department of the Interior and US Department of Agriculture 2001). Information on the effects of restoration-based fuel treatment strategies can aid in the success of future fuel management programs. We evaluate the effects of alternative treatment strategies from an ecological perspective through modeling. We begin by integrating current fire regimes from the Bitterroot Ecosystem in Western Montana into a spatially explicit simulation model and assign treatment strategies based on the dynamic changes occurring across the landscape. Next, we use the original modeled conditions as a baseline to compare ecological responses to alternative treatment strategies.

METHODS

Study Area

We used the Bitterroot Front (east side of the Bitterroot Range) in western Montana which, is composed of approximately 260,000 acres of forested land. A variety of forest types are represented along an elevational gradient ranging from approximately 4500 to 9200 feet. The forest types can be compiled into three general forest zones identified by seral species: ponderosa pine, lodgepole pine, and whitebark pine (Hartwell 1997). The ponderosa pine zone is primarily composed of ponderosa pine, western larch, and Douglas-fir with subalpine and grand fir also present in the wetter areas of the zone. Within the mid-elevation, lodgepole pine zone ponderosa pine becomes scarce and lodgepole co-dominates with Douglas-fir and subalpine fir. The whitebark pine zone is dominated by the presence of whitebark pine, subalpine fir, lodgepole pine, and alpine larch.

Evidence of fire in the study area is well represented by a number of fire history studies (Barrett and Arno 1982, Arno and Petersen 1983, Arno et al. 1993, 1995, Hartwell 1997). A variety of fire regimes exist, ranging from those characterized by non-lethal understory fires to stand-replacement fires. Evidence of ecosystem change due to fire exclusion during the 20th century is also prevalent. Using quantitative techniques to reconstruct historic forests for three forested faces on the Bitterroot Front, Hartwell (1997) measured landscape changes in forest structures between 1900 and 1995. His results show dramatic decreases in fire-dependent species such as ponderosa pine, western larch, and whitebark pine and increases in fire-intolerant species such as Douglas-fir and lodgepole pine throughout all elevation zones.

In analyzing the effectiveness of the prescribed natural fire program[5] within the Selway-Bitterroot Wilderness (west and adjacent to study area), Brown et al. (1994) estimated that the pre-settlement (before 1935) area burned was 1.7 times greater than that burned during the recent (1979-90) period. When stratified by fire severity classes, they estimated that stand-replacement fire was 1.5 times greater and non-lethal understory fire 1.9 times greater during the pre-settlement period.

Fire Regime & Condition Class

An ArcInfo polygon coverage of the study area was acquired from the USFS RMRS Forest Sciences Lab. Polygons depict individual forest stands defined by unique combinations of habitat type group, cover type, size class-structure, and canopy density and were derived primarily from air photo interpretation (Chew pers. comm. 2002). The average stand size is 51 acres, with a standard deviation of 276 acres. Median stand size is 16 acres.

The modeling rules developed by Jones et al. (2002) for estimating historical fire regime, current fire severity, and the concomitant condition class are the basis for analyzing departure from historical conditions in this project. Furthermore, the condition class ruleset is later used to differentiate between and assign treatment strategies (e.g., treat condition class 1 areas) during simulation modeling. These rulesets incorporate commonly used ecological descriptors – ecological subregions (McNab and Avers 1994), potential vegetation type (PVT), topographic variables (slope & aspect), and current vegetation (cover type, size class, & canopy density) – into a rule-based modeling approach.

A Geographic Information System (GIS) was used to apply the modeling rules to the polygon coverage and thereby map the historical fire regime, current fire severity, and condition class of the study area (Appendix A). Differences in the way the study area coverage and modeling rules describe biophysical and vegetative attributes, however, required the development of crosswalks for habitat group, slope class, aspect class, fire tolerance, size class and density class.

Historical Fire Regime

A fire regime classification developed for Northern Rocky Mountain forests was used for this project (Barrett 2002) (Table 1). Six categories of fire regimes are defined by fire

[5] The USDA Forest Service and the USDI National Park Service initiated the prescribed natural fire program around 1970 in an effort to reintroduce fire into some large park and wilderness areas.

frequency (i.e., mean fire interval) and severity (% of overstory replacement) (Barrett 2002).

Table 1. Characterization of historical fire regimes[1].

Fire Regime Class	Fire Regime	Severity (% Overstory Replacement)	Fire Interval (Years)
MS1	Short-Interval Mixed-Severity	Low – 20-30%	20 to 40
MS2	Long-Interval Mixed-Severity	Moderate – 30 – 80%	40 to 120
MS3	Variable-Interval Mixed-Severity	Variable – 10 – 90%	45 to 275
NL	Non-Lethal	Low - < 20%	10 to 25
SR1	Short-Interval Stand Replacement,	High - > 80%	95 to 180
SR2	Long-Interval Stand Replacement	High - > 80%	200 to 325

[1]The characterization of fire regimes was adapted from Barrett (2002).

Simulation Modeling

Twenty-five, 10-decade SIMPPLLE simulations were run for each of eight treatment strategies. We believe this is an adequate time frame and number of simulations to capture the natural variability present on the Bitterroot Front.

SIMPPLLE is a knowledge-based, spatiality explicit modeling system for simulating vegetative change at landscape scales (Chew 1995). Changes in vegetative composition, structure, and density are simulated as a result of stochastic disturbance processes, succession, and management. The model is not designed to try to predict the precise location, timing, or extent of processes but rather provide a range of possible outcomes useful in predicting general trends on a specific landscape. The modeling logic within SIMPPLLE is compartmentalized into individual data structures allowing flexibility in adapting the system to new areas and making updates. The data structures are collectively referred to as system knowledge.

Treatment Strategies

Landscape scale fuel management tends to be limited in the amount, location, and kind of treatment permitted. In this project treatment strategies were defined by condition class and whether or not suppression was applied to wilderness. Treatments were further constrained to roaded areas and to non-lethal (*NL*); short-interval, mixed-severity (*MS1*); and long-interval, mixed-severity (*MS2*) historical fire regimes. None of the study area was classified as having a long-interval, stand-replacement (*SR2*) historical fire regime, which generally occurs on highly productive sites rare to the study area, such as those in the western hemlock/red cedar or moist subalpine fir PVTs (Barrett 2002). Furthermore, it was decided not to treat areas within variable-interval, mixed-severity (*MS3*) and short-interval, stand-replacement (*SR1*) historical fire regimes because it is assumed within the CFS/CC modeling rules that the potential fire severity on these regimes would not be different from that experienced historically as a result of fire exclusion (Jones et al. 2002).

The eight strategies applied are:

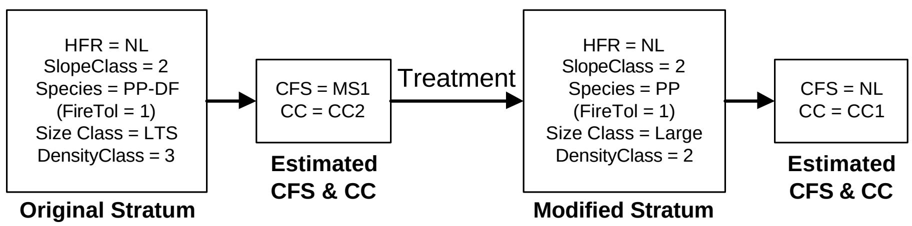
- Treat condition class 1 areas. Apply suppression in Wilderness.
- Treat condition class 1 areas. No suppression in Wilderness (Wildland Fire Use).
- Treat condition class 2 areas. Apply suppression in Wilderness.
- Treat condition class 2 areas. No suppression in Wilderness (Wildland Fire Use).

- Treat condition class 3 areas. Apply suppression in Wilderness.
- Treat conditi on class 3 areas. No suppression in Wilderness (Wildland Fire Use).
- No treatment. Apply suppression in Wilderness.
- No treatment. No suppression in Wilderness (Wildland Fire Use).

Treatment Schedules

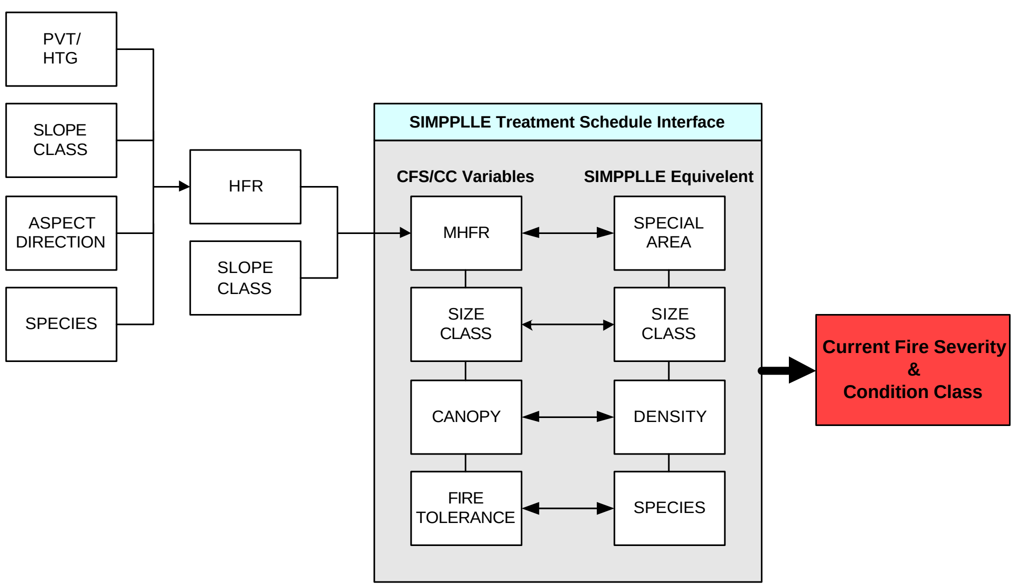
The intent of strategies 1 – 6 is to restore vegetative conditions, through the application of treatments, to a state considered to be within a natural range of variability (i.e., condition class 1). Therefore, the treatments within each strategy modify a stratum of species composition, size class-structure, and density to represent condition class 1 (Figure 1). The intent of strategies seven and eight is to simulate the response of condition class to no management action other than suppression.

Figure 1. General flow of restoration treatment.



The treatment schedule interface in SIMPPLLE was used to assign treatments in accordance with the strategy being modeled (Figure 2).

Figure 2. Flow chart of modeling approach.



The criteria (combinations of special area, species, size class-structure, and canopy density) used within the CFS/CC ruleset to model a specific condition class were defined within the treatment schedule interface for each strategy. In using this method, a treatment schedule is dynamically built at the beginning of each time step by selecting communities that meet the defined criteria. Treatments are therefore applied based on the dynamic changes to condition class that the model projects to occur.

The results of the treatment strategy simulations were imported into a database. Queries were developed to recalculate the current fire severity and condition class of each vegetative community at the end of time step ten, for each of the 25 simulations. Additional queries were then developed to determine the average acres (n=25) within each current fire severity and condition class, the results of which were stratified by historical fire regime.

A graphical analysis was used to compare the response of current fire severity and condition class to each treatment strategy. The current fire severity and condition class modeled before simulations (time step zero) was used as a baseline to determine positive or negative change from an ecological restoration perspective.

RESULTS

We present changes in vegetative condition as a result of alternative treatment strategies as projected by multiple 100-year simulations using the SIMPPLLE model. The current modeled conditions were used as a baseline with which to compare the projected current fire severity and condition class of each treatment strategy. Results are stratified by historical fire regime.

Treatment Strategy Simulation Modeling

The response of current fire severity and condition class to each treatment strategy was analyzed for the *NL*, *MS1*, and *MS2* historical fire regimes (Tables 2 & 3). Again, because changes in current fire severity and condition class are not detectable within the *MS3* and *SR1* regimes (Jones et al. 2002) they were omitted from this analysis.

Table 2. Change in percent area of current fire severity classes stratified by historical fire regime and 100 year treatment strategy.

		--Treatment Strategy[1]---							
HFR/ CFS[2]	**Original[3]**	**CC1-S**	**CC1-NWS**	**CC2-S**	**CC2-NWS**	**CC3-S**	**CC3-NWS**	**NT-S**	**NT-NWS**
		------------------------------------Percent change (acres) of HFR--------------------------------------							
NL									
MS1	18	17	14	9	5	19	17	21	20
MS2	17	7	7	5	5	-14	-14	8	8
NL	42	-6	-3	4	8	-9	-7	-11	-10
SR	22	-17	-17	17	-18	4	5	-17	-17
NS	1	0	-1	-1	-1	0	-1	-1	-1
MS1									
MS1	46	-6	-3	4	8	-9	-6	-11	-10
MS2	49	9	6	-1	-5	11	8	14	12
SR	3	-1	-1	-1	-1	0	-1	-1	-1
NS	2	-2	-2	-2	-2	-1	-2	-2	-2
MS2									
MS2	77	-1	-1	0	0	-2	-2	-1	-1
SR	21	-2	-4	-3	-5	-2	-4	-2	-4

NS	2	3	5	3	5	4	5	3	5

[1] Strategies: CC = condition class, S = apply suppression in Wilderness, NWS = no suppression in Wilderness. Average of 25 simulations.
[2] Historical fire regimes: NL = non-lethal, MS1 = short-interval mixed-severity, MS2 = long-interval mixed-severity. [2] Condition class: 1 = low departure from historical conditions, 2 = moderate departure from historical conditions, 3 = high departure from historical conditions, NS = non stocked. Current fire severity: NL = non-lethal, MS1 = low mortality mixed-severity, MS2 = high mortality mixed-severity, SR = stand-replacement, NS = non stocked.
[3] Original = before simulations (time step 0).

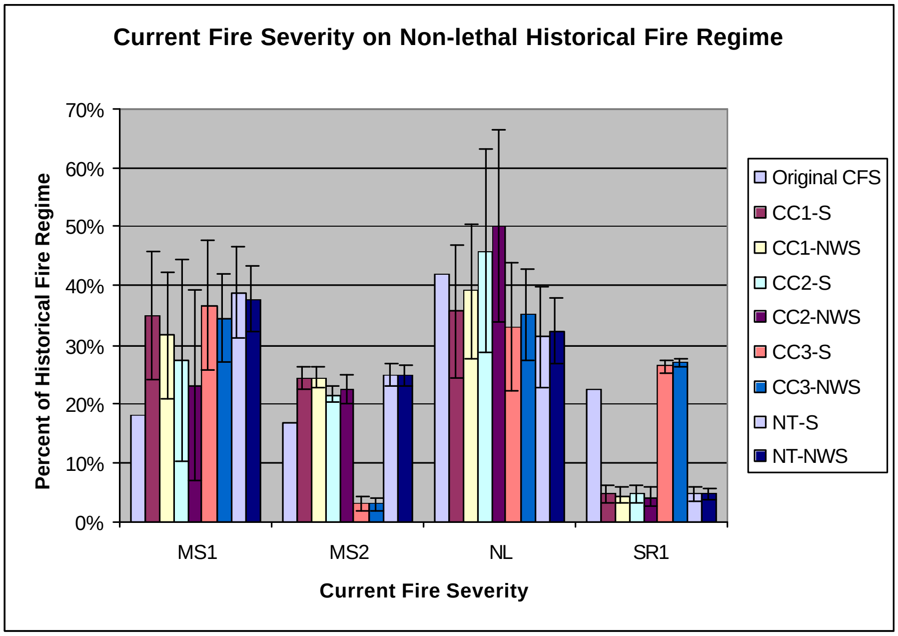
Table 3. Change in percent area of condition classes stratified by historical fire regime and 100 year treatment strategy.

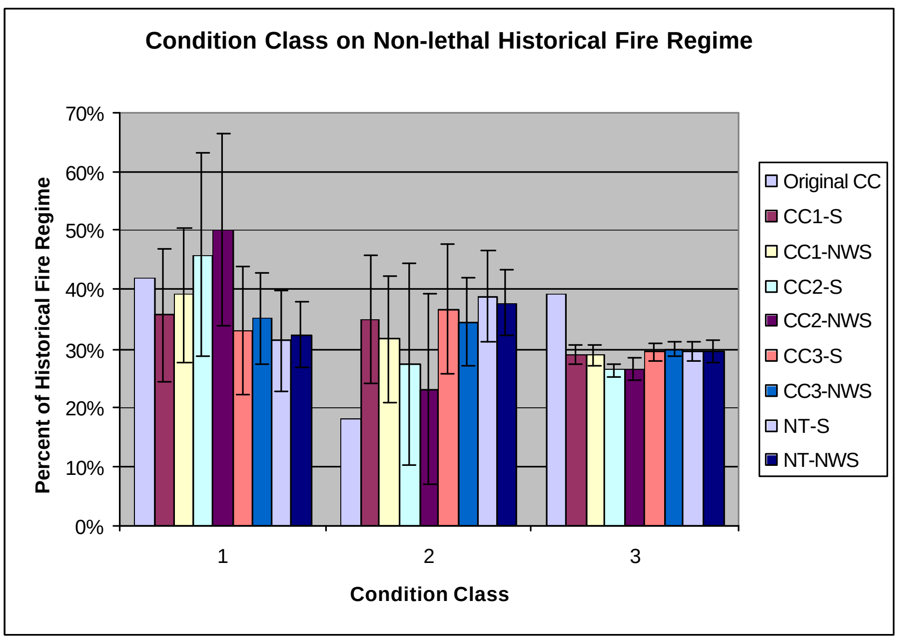
		Treatment Strategy[1]							
HFR/CC[2]	Original[3]	CC1-S	CC1-NWS	CC2-S	CC2-NWS	CC3-S	CC3-NWS	NT-S	NT-NWS
	Percent change (acres) of HFR								
NL									
CC1	42	-6	-3	4	8	-9	-7	-11	-10
CC2	18	17	14	9	5	19	17	21	20
CC3	39	-10	-10	-13	-13	-9	-9	-9	-10
NS	1	0	-1	-1	-1	0	-1	-1	-1
MS1									
CC1	46	-6	-3	4	8	-9	-6	-11	-10
CC2	19	9	8	1	-2	14	12	13	+12
CC3	33	-1	-3	-3	-4	-3	-4	-1	-1
NS	2	-2	-2	-2	-2	-1	-2	-2	-2
MS2									
CC1	77	-1	-1	0	0	-2	-2	-1	-1
CC2	21	-2	-4	-3	-5	-2	-4	-2	-4
NS	2	3	5	3	5	4	5	3	+5

[1] Strategies: CC = condition class, S = apply suppression in Wilderness, NWS = no suppression in Wilderness. Average of 25 simulations.
[2] Historical fire regimes: NL = non-lethal, MS1 = short-interval mixed-severity, MS2 = long-interval mixed-severity.
[2] Condition class: 1 = low departure from historical conditions, 2 = moderate departure from historical conditions, 3 = high departure from historical conditions, NS = non stocked. Current fire severity: NL = non-lethal, MS1 = low mortality mixed-severity, MS2 = high mortality mixed-severity, SR = stand-replacement, NS = non stocked.
[3] Original = before simulations (time step 0).

Within the *NL* historical fire regime the strategies that treat *CC2*, *CC2* with wilderness suppression (CC2-S) and *CC2* without wilderness suppression (CC2-NWS), increased the amount of area classified as having a fire severity characteristic of the historical regime (non-lethal). Accordingly, the amount of area classified as *CC1* was also increased by these two strategies. All strategies, with the exception of those treating *CC3* with and without wilderness suppression (CC3-S and CC3-NWS respectively), result in a dramatic decrease in the amount of area expected to burn with stand-replacement severity while increasing the amount of area in a mixed-severity classification. Likewise, all strategies were shown to increase the amount of area classified as *CC2* while decreasing *CC3* (Figure 3).

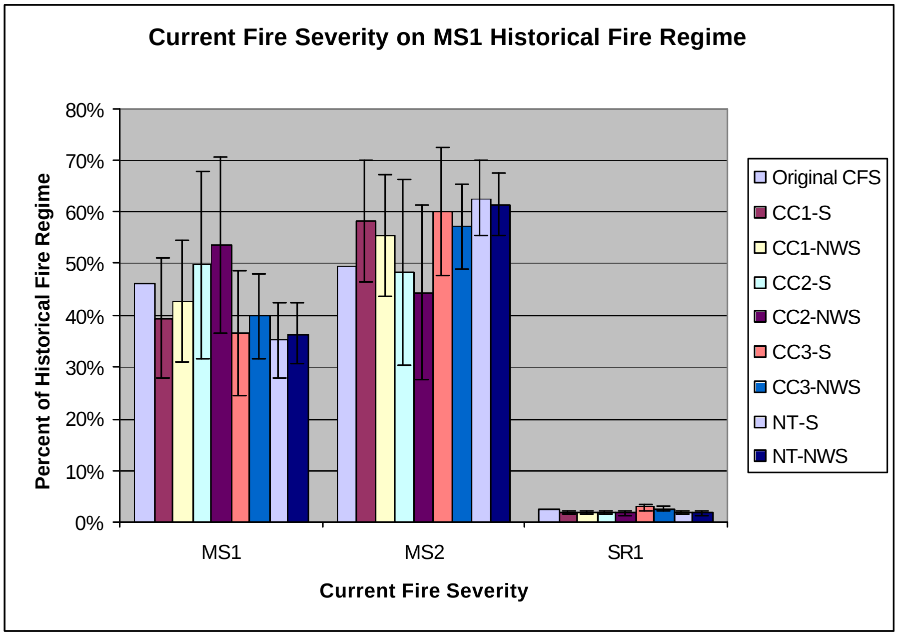
Figure 3. Results of treatment strategy modeling on non-lethal historical fire regime. (Error bars represent percent standard deviation)

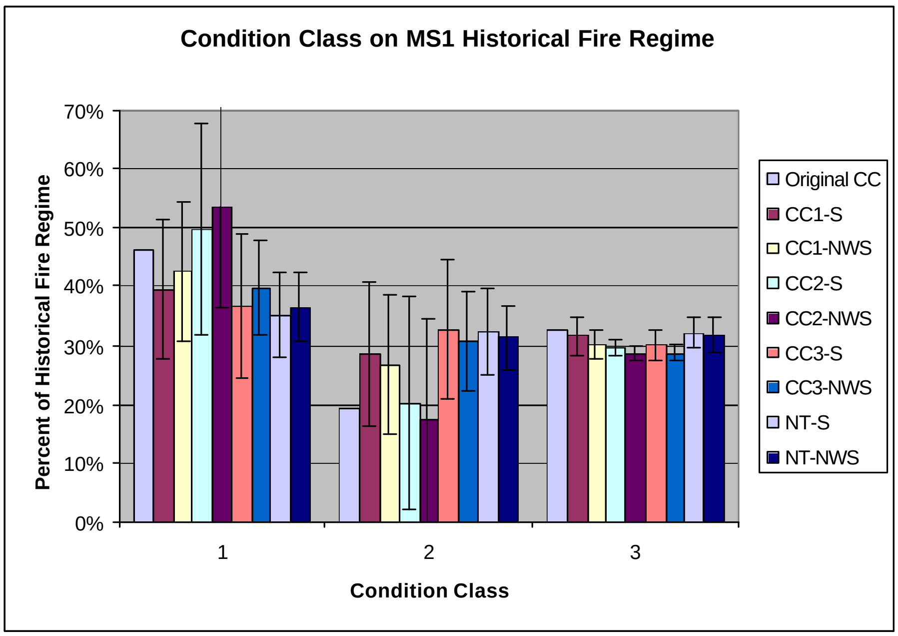




Within the *MS1* historical fire regime the amount of area classified with a stand-replacement fire severity and subsequent *CC3* remains relatively unchanged compared to the original conditions. The CC2-S and CC2-NWS strategies result in an increase in the amount of area expected to receive a characteristic fire severity and subsequent *CC1* classification. Conversely, all other strategies show an increase in *MS2* and decrease in *MS1* severity. Likewise, all strategies, with the exception of the CC2-NWS, were shown to increase the amount of area classified as *CC2* while decreasing *CC3* (Figure 4).

Figure 4. Results of treatment strategy modeling on short-interval, mixed-severity historical fire regime. (Error bars represent percent standard deviation)





Within both the *NL* and *MS1* regimes the model indicated that for any given condition class prioritization (i.e.; *CC1*, *CC2*, *CC3*, or no treatment) the no wilderness suppression strategy resulted in more land being restored to a *CC1* state than did the suppression strategy (Figures 3 and 4).

DISCUSSION

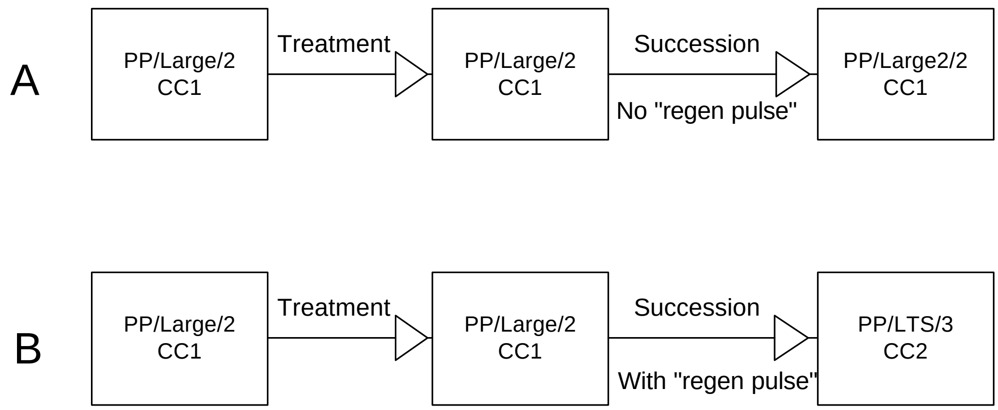
As with any modeling exercise one must interpret these results with an understanding of the assumptions in the models. Moreover, in integrating the rule-based fire regime models with the SIMPPLLE model additional assumptions were made in order to address the differences between them. In some cases, these assumptions heavily influenced the results of this study. Nevertheless, this study provides insight into changes in vegetative condition in response to the spatial and temporal interactions of natural processes and fuel treatments.

Treatment Strategy Simulation Modeling

These simulations depict the spatial and temporal interactions of natural disturbance processes and succession occurring simultaneously with fuel treatment. The resulting distribution of condition class represents the effect of these interactions on vegetative conditions over a ten-decade period. It was not possible to track change in condition class over time and therefore the actual path of any given community is uncertain, however, inferences are made by comparing original and decade ten conditions.

The CC1 strategies (CC1-S and CC1-NWS) can be thought of as "maintenance" approaches to fuel treatment. The intent of these strategies was to gain an understanding of the effect natural disturbance processes and succession would have on vegetative conditions, under current fire suppression policies, while maintaining areas that have not departed from their historical fire regime. For instance, would the balance of natural disturbance and succession restore vegetative communities at a rate greater than that in which they are departing thereby adding to the net *CC1*, maintain the current level of *CC2* and *CC3*, or increase *CC3*? The results suggest that these strategies were ineffective at meeting this intent and therefore further interpretations will not be made. The ineffectiveness of these strategies is an artifact of an assumption made in the modeling approach. In developing pathway modifications to the SIMPPLLE model (see methods) it was assumed that the establishment of understory tree species on drier habitat types of the Bitterroot Front is the result of a suite of stochastic environmental conditions leading to a regeneration pulse. This assumption had a major influence on the CC1 strategy results thereby limiting comparison to other strategies. Because treatments are modeled at the beginning of a time step the maintenance of a *CC1* community is actually dependent on the probability of a regeneration pulse not occurring rather than the actual treatment being applied (Figure 5). For example, if a regeneration pulse (stochastic event) were predicted to occur the stratum of vegetative attributes could, depending on the specific habitat and cover type, be altered to that of *CC2* thereby discontinuing treatment in the next time step.

Figure 5. Effect of regeneration pulse on CC1 strategies. A: no regeneration pulse results in maintenance of CC1 state. B: Regeneration pulse results in an increase of density and subsequent CC2 state.

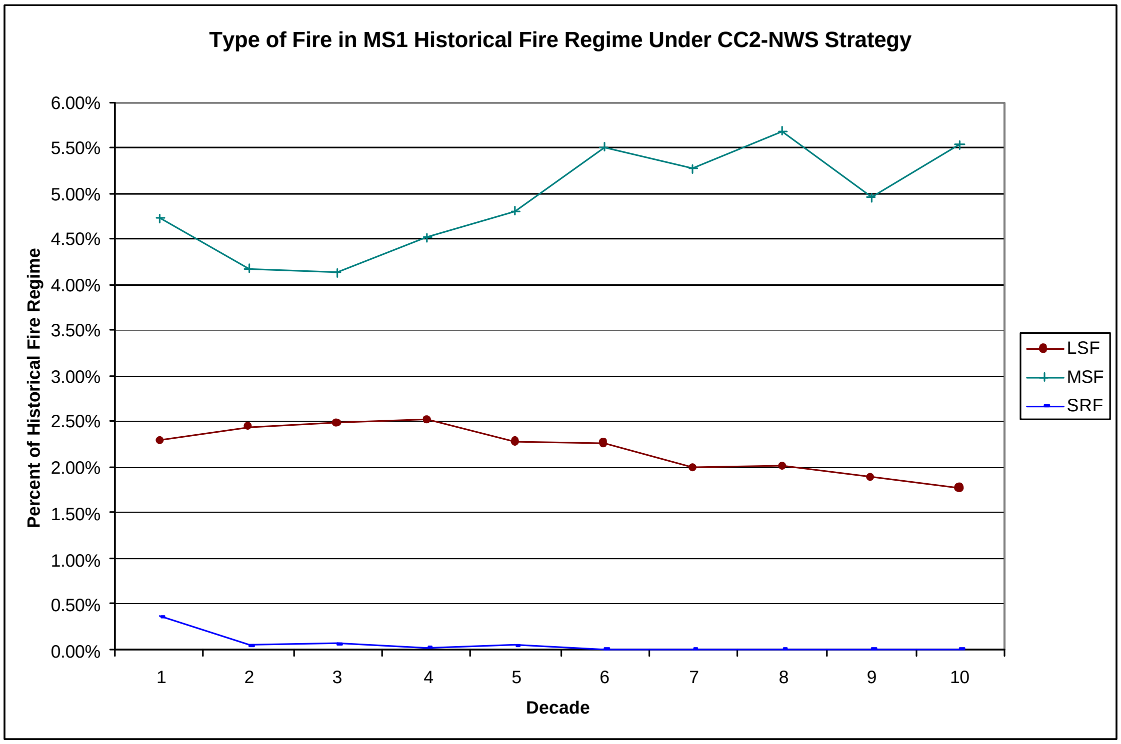


The only way the community would ever be re-treated is if a disturbance process, which restored the community to a *CC1* stratum were predicted to occur. In future applications alternative methods should be developed to represent the maintenance of *CC1* communities.

The CC2 strategies (CC2-S and CC2-NWS) restore areas that have moderately departed from their historical fire regime (i.e., *CC2*), through the application of treatment, at the beginning of each time step. The treatment logic restores the community to a stratum of composition, size class-structure, and density required for a *CC1* classification[6]. These communities may eventually reach *CC2* again as a result of forest succession in which case they would be re-treated. As previously mentioned, it is not possible to track the actual history of any one community or group of communities over time. Therefore, it is unclear what proportion of the total acreage of *CC1* in decade ten is a result of treatments restoring *CC2,* natural processes maintaining *CC1*, or natural processes restoring *CC3* (Figures 3 and 4). It is also unclear what proportion of the net increase of *CC2* observed within the *NL* regime has resulted from restoration of *CC3* or departure from *CC1* (Figure 3). However, in comparing the results of the CC2 strategies within the *NL* regime with those within the *MS1* regime a much subtler change in *CC2* and *CC3* is observed within *MS1* (Figures 3 and 4). In reality, it would be expected to have less frequent fire in the mixed-severity regime than in the non-lethal. It could be hypothesized therefore that within the *NL* regime natural processes are restoring *CC3* to *CC2*, and within both regimes treatment is restoring *CC2* to *CC1* at a rate slightly greater than that in which it is departing. Simulation results further support this hypothesis where more stand-replacement fire is observed within the *NL* than the within the *MS1* historical fire regime (CC2-NWS strategy, Figure 6).

[6] By definition, there are a few cases in which the treatment logic does not restore *CC1* but maintains the *CC2* stratum. These cases are unique, however, in that within these communities an increase in size class will reduce the expected fire severity therefore restoring *CC1* (Appendix C).

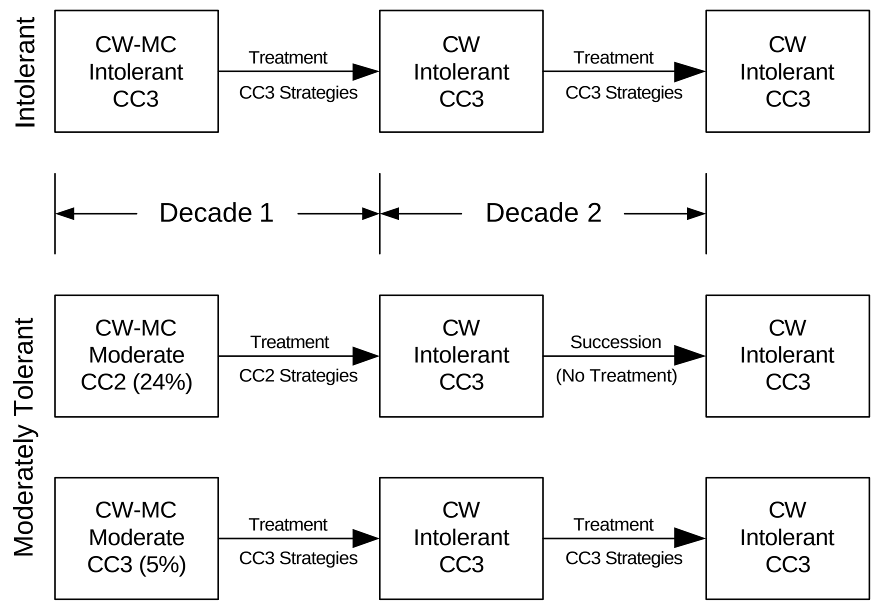
Figure 6. Simulated wildland fire under CC2-NWS strategy on non-lethal and short-interval, mixed-severity historical fire regimes.



The CC3 strategies (CC3-S and CC3-NWS) target areas that have significantly departed from their historical fire regime and are therefore at the greatest risk of losing key ecological components in the event of a fire. Although it may have been expected that these would be effective restoration strategies a decrease in *CC1* from original conditions resulted suggesting an increasing rate of departure (Figures 3 and 4).

Within the *NL* historical regime, modeling assumptions had a large influence on the CC3 strategy results thereby limiting comparison to other strategies. As discussed above it was assumed that coniferous riparian areas would be characterized by the historical fire regime of their adjacent upland counterparts thereby classifying all CW-MC communities with an *NL* historical fire regime. Given this assumption treatment of the CW-MC communities had no effect on condition class (Figure 7). For example, according to the treatment logic of the SIMPPLLE model, treating a CW-MC cover type results in removal of the MC component thus re-coding the community as CW, also an intolerant cover type. Therefore, because the CFS/CC models assign *CC3* whenever a fire-intolerant cover type is established on a *NL* historical fire regime, SIMPPLLE applies treatment to the resulting CW communities at the beginning of each time step for the remainder of the simulation with no effect on condition class.

Figure 7. Effects of treating coniferous riparian cover types on NL historical fire regime using two separate fire tolerance classifications.



Furthermore, unlike with the CW-MC cover type there is no discrepancy as to the fire tolerance of CW between models; both consider it as intolerant. Therefore, even if a moderate fire tolerance had been assigned to CW-MC, treatment in the first time step would covert the community to a fire intolerant, CW cover type and subsequent *CC3* classification for the remainder of the simulation (Figure 14). If a moderate fire tolerance had been used, 24% of the CW-MC would be classified as *CC2* and 5% as *CC3*. Therefore, the difference would be that the majority of the CW-MC would be treated under the CC2 strategies rather than the CC3.

Within the *MS1* regime the CC3 strategies are not limited by the assumptions discussed above. Coniferous riparian cover types make up only 3% of the communities within this regime. Nevertheless, these strategies were still less effective than the CC2 strategies at restoring *CC1* (Figures 9 and 10). In comparing the CC3 strategy results to the NT results little difference is observed within *CC3* communities suggesting that neither natural disturbance nor treatment was effective at restoring *CC3* within this regime. The following factors support this hypothesis. Although it is unclear how much of the original *CC3* was retained through the entire simulation, less than 0.25% of the communities within the regime experienced stand-replacement fire in any time step (CC3-NWS strategy, Figure 7) suggesting that *CC3* communities were not predicted to experience fire events and therefore natural disturbance was less likely to bolster the restoration of *CC3* communities within the time frame modeled. Furthermore, 24% of the area within the *MS1* regime is not roaded and therefore unavailable for treatment and by definition treatment of *CC3* communities does not always result in restoration to a lower condition class (Appendix C).

The NT strategies (NT-S and NT-NWS) result in a reduction of *CC1* and increase of *CC2* from original conditions on both the *NL* and *MS1* historical fire regimes (Figures 9 and 10). These results suggest that in the absence of treatment communities are continuing to depart from historical conditions at a rate greater than that which is being maintained or restored by natural processes on these regimes. Furthermore, these results suggest that natural disturbance has a greater influence on reducing *CC3* within the *NL* regime than the *MS1* (Figures 3 and 4). Since no treatment is applied under these strategies the effects of natural disturbances and succession simulated by the SIMPPLLE model dictate the condition class distribution within all fire regimes.

Comparison between treatment strategies is limited due to assumptions made in the modeling process mentioned above. However, in analyzing strategies individually some inferences can be made. For instance, a trend observed across all strategy couplets (e.g., CC1-S and CC1-NWS) is that of an increase of *CC1* and decrease of *CC2* when no suppression is applied to wilderness (Figures 9 and 10). This result suggests that wildland fire use in wilderness may be an effective restoration strategy. Furthermore, these simulations suggest that the balance of natural disturbance and succession has a significant influence on the resultant vegetative conditions regardless of where treatment is applied. That is, regardless of the strategy being modeled an increase or decrease in one condition class leads to equal changes in the other condition classes given a fixed number of acres.

Finally, because the trajectory of any given community is unique, the applicability of these results to different landscapes is limited. For instance, the factors that influence model results (e.g., biophysical variables, probability of disturbance processes, suppression effectiveness) can vary considerably between landscapes.

Modeling Pitfalls

The increase of high severity fire potential in forests that historically have experienced low-severity fire regimes is consistent with the findings of other fire history research within the study area (Arno et al. 1993, 1995, Hartwell 1997). A number of factors have been associated with this change including extensive livestock grazing, cessation of Native American burning, and decades of successful fire suppression (Brown and Smith 2000). The distribution of current fire severity and condition class modeled on the landscape is largely influenced by the vegetative attributes used in the modeling rules. The need to develop crosswalks that define a common vegetative classification system was essential in integrating the CFS/CC models with the SIMPPLLE model, however, differences in how the models describe the fire tolerance of cover types, specifically Douglas-fir (DF) and cottonwood/mixed-conifer (CW-MC) had a significant influence on the current fire severity and condition class modeling results[7]. Although the CFS/CC models are very sensitive to the fire tolerance of cover types, it was decided to use the fire tolerance classifications of the SIMPPLLE model since they are germane to the cover types used in the Bitterroot Front dataset as well as the type of fire and fire spread logic used in the subsequent simulation modeling. However, the original condition class distribution would be different had the fire tolerance classifications of the CFS/CC modeling rules been used. For example, The DF cover type is assigned to 15%, 33%, and 47% of the *NL, MS1,* and *MS2* historical fire regimes, respectively. SIMPPLLE classifies DF as a fire tolerant cover type while the CFS/CC models classify it as moderately tolerant. If the CFS/CC tolerances had been used a decrease of *CC1* and increase of *CC3* would have resulted (Table 4).

[7] Discrepancies also exist for the grand fir and western larch cover types. However, these cover types are assigned to less than 0.001% of the *NL*, *MS1*, and *MS2* historical fire regimes combined.

Table 4. Comparison of condition class distribution in NL, MS1, and MS2 historical fire regimes using different fire tolerance classifications for Douglas-fir cover type.

	----Condition Class2----				
Historical Fire Regime1/ Fire Tolerance	1	2	3	NS	Total
	----------------------Percentage ----------------------				
NL					
Intolerant (SIMPPLLE)	42	18	39	1	100
Moderately Tolerant (CFS/CC)	35	18	46	1	100
MS1					
Intolerant (SIMPPLLE)	46	19	33	2	100
Moderately Tolerant (CFS/CC)	40	10	48	2	100
MS2					
Intolerant (SIMPPLLE)	77	21	--	2	100
Moderately Tolerant (CFS/CC)	72	26	--	2	100

[1]Historical fire regimes: NL = non-lethal, MS1 = short interval mixed severity, MS2 = long interval mixed severity. [2]Condition class: 1 = low departure from historical conditions, 2 = moderate departure from historical conditions, 3 = high departure from historical conditions, NS = non stocked.

The CW-MC cover type primarily influences the *NL* historical fire regime where it is assigned to 29% of the communities within the regime. Although differences in how the models describe the fire tolerance of this cover type influenced the resulting condition class distribution (Table 5), the more pertinent issue is that a conflict exists between the cover type and the historical fire regime in which it is established.

Table 5. Comparison of condition class distribution in non-lethal historical fire regime using different fire tolerance classifications for cottonwood-mixed conifer cover type.

	--------Condition Class 1-------				
Fire Tolerance	1	2	3	NS	Total
Intolerant (SIMPPLLE)	42	18	39	1	100
Moderately Tolerant (CFS/CC ruleset)	42	42	15	1	100

1Condition class: 1 = low departure from historical conditions, 2 = moderate departure from historical conditions, 3 = high departure from historical conditions, NS = non stocked.

Within the CFS/CC modeling rules (Appendix C) neither an intolerant nor moderately tolerant cover type can be classified as *CC1* within an *NL* historical fire regime suggesting that coniferous riparian cover types, such as CW-MC, historically did not exist within this regime. In developing the modeling rules Jones et al. (2002) assumed that the historical fire regime of coniferous riparian areas would be the same as adjacent upland areas. Although historically CW-MC communities most likely experienced frequent fire as did their adjacent counterparts of Douglas-fir and ponderosa pine, (USDA Fire Effects Information System 2002) the fire severity would likely be one of high mortality (Brown 1996, Gom and Rood 1999). Future applications of this modeling approach should therefore consider making refinements to historical fire regimes based on the presence of riparian cover types.

A third assumption influencing how one interprets the CFS/CC modeling results is that the fire severity potential has not measurably changed within the *MS3* and *SR1* historical fire regimes as a result of fire exclusion (Jones et al. 2002). Acknowledgement of this assumption is particularly important when interpreting the results at different observational scales. For instance, although from a management perspective 73% of the entire landscape being classified as *CC1* (Figure 8) may appear desirable, 39% of the non-lethal historical fire regime classified as *CC3* (Table 11) would not. The high percentage of *CC1* at the landscape scale is attributed to 40% of the landscape being characterized by an *MS3* or *SR1* historical fire regime (Figure 8), which based on this assumption can be classified only as *CC1* (Appendix E). Jones et al. (2002) attribute the inability of the CFS/CC models to detect change in fire severity potential within these regimes to the resolution of the data used to define modeling rules rather than actual ground conditions. For instance, it has been suggested that fire exclusion can affect stand-replacement fire regimes, (Arno et al. 1993, Baker 1993, Hessburg et al. 1999, Arno 2000, Barrett 2002) where changes are revealed in landscape scale patterns and processes such as increased homogeneity and spatial extent of stand-replacement fire. However, fuels play a major role in limiting the spread of fire in stand-replacement fire regimes (Arno 2000); an attribute not incorporated in the modeling rules.

CONCLUSIONS

Managing ecological systems today involves a broad spatial and temporal perspective. Resource management has shifted focus from the stand level to that of watersheds and entire landscapes and recognizes the importance of disturbance regimes on past, present, and future conditions. The interrelations of fire and vegetative succession are perhaps the greatest influence on the landscape dynamics of Northern Rocky Mountain ecosystems. Combining the condition class concept with the SIMPPLLE model provided a means with which to evaluate the impacts of fuel treatment strategies in the context of this disturbance-driven spatial and temporal variability.

The historical fire regime and current fire severity/condition class models suggest that fire exclusion has led to departure from historical conditions on the Bitterroot Front. Much of the area that was historically characterized by low mortality fire regimes (*NL* and *MS1*) is now expected to experience high mortality fires (*MS2* and *SR1*). In the present simulations, the CC2 strategies were the most effective at restoring *CC1*. Results of the NT strategies suggest that in the absence of treatment, communities will continue to depart from historical conditions at a rate greater than that which is being maintained or restored by natural processes and that natural disturbance has a greater influence on reducing *CC3* within the *NL* historical fire regime than the *MS1* regime. Comparing the results of the CC2 and NT strategies with those of the CC1 and CC3 strategies is limited, however, due to the effect of assumptions made in the modeling approach. Nevertheless, this study provides insight as to changes in vegetative condition in response to the spatial and temporal interactions of natural processes and fuel treatments.

While the treatment strategies simulated in this study are simplified from a management perspective, the modeling approach identifies key issues, which provides a first step toward examining a more complex set of fire management problems. Future applications would benefit by resolving conflicts between initial and derived data layers (e.g., current vegetation and historical fire regime) and developing methods with which to track condition class over time.

REFERENCES

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press: Washington, D.C. 493 pp.

Arno, S.F. 2000. Chapter five: Fire in Western forest ecosystems. In: Brown, J.K.; Smith J.K., eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: US Department of Agriculture, Forest Service, Rocky Mountain Research Station: 97-120.

Arno, S.F.; Sneck, K.M. 1977. A method for determining fire history in coniferous forests of the Mountain West. Gen. Tech. Rep. INT-42. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 28 pp.

Arno, S.F.; Petersen, T.D. 1983. Variation in estimates of fire intervals: A closer look at fire history on the Bitterroot National Forest. Research Paper INT-301. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 pp.

Arno, S.F.; Reinhardt, E.D.; Scott, J.H. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: A procedure for quantifying past and present conditions. Gen. Tech. Rep. INT-294. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Research Station. 17 pp.

Arno, S.F.; Scott, J.H.; Hartwell, M.G. 1995. Age-class structure of old growth ponderosa pine/Douglas-fir stands and its relationship to fire history. Research paper INT-RP-481. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Research Station. 25 pp.

Baker, W.L. 1993. Spatially heterogeneous multi-scale response of landscapes to fire suppression. *Oikos* 66, 66-71.

Barrett, S.W.; Arno, S.F. 1982. Indian fires as an ecological influence in the Northern Rockies. *Journal of Forestry* 80, 647-651.

Barrett, S.W.; Arno, S.F. 1988. Increment borer methods for determining fire history in coniferous forests. Gen. Tech. Rep. INT-244. US Department of Agriculture, Forest Service, Intermountain Research Station. 15 pp.

Barrett, S.W. 2002. A fire regimes classification for Northern Rocky Mountain forests: Results from three decades of fire history research. Office report on file, Planning Division, USDA Forest Service Flathead National Forest, Kalispell MT. 61 pp.

Brown, J.K. 1996. Fire effects on aspen and cottonwood. In: Aspen and cottonwood in the Blue Mountains: Workshop; 1996 April 2-4; La Grande, OR. La Grande, OR: Blue Mountains Natural Resources Institute. 11 p.

Brown, J.K.; Smith J.K., eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 pp.

Brown, J.K.; Arno, S.F.; Barrett S.W.; Menakis, J.P. 1994. Comparing the prescribed natural fire program with presettlement fires in the Selway-Bitterroot Wilderness. *International Journal of Wildland Fire* 4, 157-168.

Chew, J.D. 1995. Development of a system for simulating vegetative patterns and processes at landscape scales. Ph.D. dissertation. University of Montana, Missoula, MT. 182 pp.

Chew, J.D. 2002. Personal Communication.

Chew, J.D.; Moeller, K.; Stalling C.; Bella; E.M.; Ahl, R.S. 2002. User's Guide for SIMPPLLE, version 2.2. *Proposed* Gen. Tech. Rep. RMRS-GTR-xxx. US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 222 pp.

Cissell, J.H.; Swanson, F.J.; Weisberg, P.J. 1999. Landscape management using historical fire regimes: Blue River, Oregon. *Ecological Applications* 9(4), 1217-1231.

ESRI Inc. 2001. ArcGIS, version 8.2. Environmental Systems Research Institute, Inc. Redlands, CA. USA.

Gom, L.A.; Rood, S.B. 1999. Fire induces clonal sprouting of riparian cottonwoods. *Canadian Journal of Botany*. 77(11), 1604-1616.

Hardy, C.C.; Menakis, J.P.; Long, D.G.; Brown, J.K.; Bunnell, D.L. 1998. Mapping historic fire regimes for the western United States: integrating remote sensing and biophysical data. In: Proceedings of the 7^{th} Biennial Forest Service Remote Sensing applications conference. 1998 April 6-9; Nassau Bay, TX. Bethesda, MD: American Society for Photogrammetry and Remote Sensing. 288-300.

Hardy, C.C.; Bunnell, D.L.; Menakis, J.P.; Schmidt, K.M.; Long, D.G.; Simmerman, D.G.; Johnson, C.M. 1999. Coarse-scale spatial data for wildland fire and fuel management. USDA Forest Service Rocky Mountain Research Station, Fire Sciences Laboratory, November 1999. Online at: http://www.fs.fed.us/fire/fuelman.

Hardy, C.C.; Schmidt, K.M.; Menakis, J.P.; Sampson, R.N. 2001. Spatial data for national fire planning and fuel management. *International journal of Wildland Fire* 10, 353-372.

Harkins, K.C.; Morgan, P.; Neuenschwander, L. F.; Chrisman, A.; Zack, A.; Jacobson, C.; Grant, M.; Sampson, N. 2000. The Idaho Panhandle National Forests wildfire hazard-risk assessment. Pages 92-100 in Neuenschwander, L.G. and Ryan, K.C., technical eds. *Proceedings of the Joint Fire Science Conference and Workshop, Volume 1, June 15-17 1999, Boise, ID*.

Hartwell, M.G. 1997. Comparing historic and present conifer species compositions and structures on forested landscapes of the Bitterroot Front.

Hessburg, P.F.; Smith, B.G.; Salter, R.B. 1999. Detecting change in forest spatial patterns from reference conditions. *Ecological Applications* 9,1232-1252.

Jones, J. G.; Chew, J. D; Zuuring, H R. 1999. Applying simulation and optimization to plan fuel treatments at landscape scales. In: Gonzalez-Caban, Armando; Omi, Philip N., tech. coords. Gen. Tech. Rep. PSW-GTR-173. Proceedings of the Symposium on Fire Economics Planning, and Policy: Bottom Lines; 1999 April 5-9; San Diego, CA. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station: 229-336.

Jones, J.L.; Barrett S.W.; Berglund, D. 2002. Modeling historical and current fire regimes for major vegetation types in northern Idaho and western Montana: A first approximation. Office report on file, Planning Division, USDA Forest Service, Flathead National Forest, Kalispell, MT. 27 pp.

Keifer, M.; Caprio, A.C.; Lineback, P.; Folger, K. 2000. Incorporating a GIS model of ecological need into fire management planning. Pages 122-129 in Neuenschwander, L.G. and Ryan, K.C., technical eds. *Proceedings of the Joint Fire Science Conference and Workshop, Volume 1, June 15-17 1999, Boise, ID*.

Landres, P.B.; Morgan, P.; Swanson, F.J. 1999. Overview of the use of natural variability concepts in managing ecological systems. *Ecological Applications* 9(4), 1179-1188.

Long, D.G. 1998. Mapping historical fire regimes in northern Rocky Mountain landscapes. Thesis. University of Idaho, Moscow, Idaho. 63 pp.

McKenzie, D.; Peterson, D.L.; Agee, J.K. 2000. Spatial variation in fire frequency in the Interior Columbia River Basin. *Ecological Applications* 10, 1497-1516.

McNab, W.H.; Avers, P.E., comps. 1994. Ecological subregions of the United States: section descriptions. Administrative Publication WO-WSA-5. Washington, DC: US Department of Agriculture, Forest Service. 267 p.

Miller, C.; Landres, P.B.; Alaback, P.B. 2000. Evaluating risks and benefits of wildland fire at landscape scales. Pages 78-87 in Neuenschwander, L.G. and Ryan, K.C., technical eds. *Proceedings of the Joint Fire Science Conference and Workshop, Volume 1, June 15-17 1999, Boise, ID*.

Morgan, P.; Bunting, S.C.; Black, A.E.; Merrill, T.; Barrett, S. 1996. Fire regimes in the Interior Columbia River Basin: Past and present. Final Report for RJVA-INT-94913. On file at Fire Sciences Labboratory, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT.

Morgan, P.; Hardy, C.C.; Swetnam, T.W.; Rollins, M.G.; Long, D.G. 2001. Mapping fire regimes across time and space: Understanding coarse and fine-scale fire patterns. *International Journal of Wildland Fire* 10, 329-342.

Pfister, R.D.; Kovalchik, B.L.; Arno, S.F.; Presby, R.C. 1977. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 174 pp.

Redmond, R.L.; Hart, M.M.; Winne, J.C.; Williams, W.A.; Thorton, P.C.; Ma, Z.; Tobalske, C.M.; Thorton, M.M.; McLaughlin, K.P.; Tady, T.P.; Fisher, F.B., Running, S.W. 1998. The Montana GAP analysis project. Unpubl. Rep. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula. 136 pp.

Sampson, N.; Atkinson, D.; Lewis, J. eds. 2000. Mapping wildfire hazards and risks. The Haworth Press, Inc.

Schmidt, K.M.; Menakis, J.P.; Hardy, C.C.; Hann, W.J.; Bunnell, D.L. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station, 41pp. + CD.

US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2002, September). Fire Effects Information System, [Online]. Available: http://www.fs.fed.us/database/feis/ [Accessed September 2002].

US Department of the Interior and US Department of Agriculture. 2001. Review and update of the 1995 federal wildland fire management policy. Bureau of Land Management, Boise, ID.

WSAL. 2000. FireRisk: A fuels, fire, fire regime database. Version 1.0. Prepared for the USDA Forest Service, Northern Region by Wildlife Spatial Analysis Lab, Montana Cooperative Wildlife Research Unit, The University of Montana, Missoula, MT 59812.

SYNTHESIS

Our final objective was to combine financial, economic and ecological data to assess fuels treatments at the landscape level. We employ MAGIS and examine fuels treatment objectives focused on ecosystem restoration and reducing risk in the WUI. By changing costs, budgets and objectives, were are able to examine resource use at the landscape level.

AN ECONOMIC ASSESSMENT OF FUELS TREATMENTS AT THE LANDSCAPE LEVEL

HAYLEY HESSELN & JANET SULLIVAN

INTRODUCTION

Wildland fire plays an important role in many forested ecosystems by influencing vegetative composition and structure, landscape patterns, and ecological functions (Brown and Smith 2000). In the Northern Rocky Mountains of the United States, many of these ecosystems and their associated species are considered to be fire-adapted, meaning that they have the ability to survive and regenerate in a fire-prone environment. Historically, fire has maintained the characteristics that define these ecosystems. Land managers and researchers have begun to acknowledge that many land management policies and practices over the last century, especially fire exclusion, have resulted in major changes in how fire influences fire-adapted forest ecosystems.

In the absence of fire, forest succession leads to the replacement of fire-resistant tree species with less fire-resistant species and subsequent increases in stand density and fuel loading. These changes are most apparent within short-interval, fire-adapted systems, which historically experienced frequent, low intensity fire events, but have also occurred in ecosystems that historically experienced less frequent, high intensity events (Brown and Smith 2000). Over time, this transformation has directly affected natural fire regimes (Morgan et al. 1996, Barrett 2002, Hardy et al. 2001) resulting in uncharacteristic fire frequency, severity, and/or spatial extent.

Fire regimes refer to “the nature of fire occurring over long periods and the prominent immediate effects of fire that generally characterize an ecosystem” (Brown and Smith 2000). The fire process, however, is uniform in neither time nor space. The frequency, intensity, seasonality, extent, and other characteristics of fire, which collectively make up the fire regime, vary considerably across the landscape (Agee 1993) thus making it difficult to evaluate the impacts of altered fire regimes.

Current wildland fire management acknowledges the importance of restoring the natural ecological role of fire. In fact, the 2001 Federal Wildland Fire Management Policy states as a guiding principle that “The role of wildland fire as an essential ecological process and natural change agent will be incorporated into the planning process.” (US Department of the Interior and US Department of Agriculture 2001). Information on the effects of restoration-based fuel treatment strategies can aid in the success of future fuel management programs.

The objective of this research is to use a modeling approach to analyze the impacts of alternative fuels treatment strategies. We will combine financial, economic, and social information in a decision-making framework to evaluate the costs of alternative treatments for two objectives; (1) hazardous fuels reduction in the wildland-urban interface, and (2) restoration in fire-adapted ecosystems. These objectives are directly applicable to modeling and are consistent with the National Fire Plan. Two goals of the NFP are 1) hazardous fuels reduction and 2) restoration in fire-adapted ecosystems. Our objectives will be tied to mapping Communities at Risk (CAR) and Ecosystems at Risk (EAR). We next provide our methodology and expectations followed by a discussion of potential findings.

METHODOLOGY

We use the optimization model MAGIS (*M*ulti-resource *A*nalysis and *G*eographic *I*nformation *S*ystem) to analyze the effectiveness of fuel treatments at the landscape scale (Jones et al. 1999, Chew et al. 2000) for the Bitterroot Mountains in western Montana. "MAGIS uses optimization to select the spatial arrangement and timing of treatments that fits user-determined objectives and constraints. MAGIS users can also specify the location and timing for specific treatments to test 'what-if' scenarios" (USDA Forest Service 2003). The model integrates ecological, social, and economic information, which provides the basis from which to schedule treatments at the landscape level. MAGIS also provides as output, the ecological effects and economic outcomes. Activities that can be modeled include a wide variety of silvicultural methods such as those geared toward mechanical fuels treatments and prescribed burning.

The study site is located along the Montana/Idaho border and is approximately 96 km long. The Bitterroot Front was chosen as the study area because it is composed of approximately 105,208 hectares of forested land that represents a variety of forest types and includes a substantial wildland-urban interface component.

Simulations were set up to target fuels reductions in the wildland-urban interface and to restore ecosystems. We used a base year of 2004 with associated costs and revenues. Treatments were modeled in five 10-year time units using a discount rate of 4%.

The model parameters are based on GIS data and pathways and crosswalks designed to convert landscape data for use in MAGIS. We used five vegetative treatment types: three levels of commercial harvest (improvement cutting, commercial thinning, and seed tree cuts); a net cost mechanical treatment (precommercial thinning) and a prescription burn (ecosystem stand underburn). Costs for these activities were confirmed by the Forest Service, and were calculated based on logging methods (tractor, helicopter, cable and skyline). Mechanical treatments resulting in net costs included pre-commercial thinning and slashing. Costs for these activities are listed in Table 1.

Table 1: Treatments and Costs

Cost Name	Unit of Measure	Cost Method	Single Cost ($)
Improvement Cut*	ccf SawLogs	Table Lookup	na
Commercial Thin*	ccf SawLogs	Table Lookup	na
Seed Tree Cut*	ccf SawLogs	Table Lookup	na
Precommercial Thin	ACRE	Single Cost	225
Slashing	ACRE	Single Cost	350
Ecoburn Underburn timber	ACRE	Single Cost	80
NEPA Costs ccf	ccf SawLogs	Single Cost	18
Monitoring management	ACRE	Single Cost	5
Monitoring regeneration	ACRE	Single Cost	12
Handpile after slash	ACRE	Single Cost	200
Ips beetle clean-up	ACRE	Single Cost	600
Scatter activity debris by hand	ACRE	Single Cost	300
* These items calculated by logging method			
Tractor (Rd == 35%)	ccf SawLogs	Table Lookup	8
Helicop (assigned to All	ccf SawLogs	Table Lookup	64

WILD)			
Cable (Rd > 35%)	ccf SawLogs	Table Lookup	30
Skyline	ccf SawLogs	Table Lookup	40

Other management activities used for ecosystem restoration include slashing, monitoring, hand piling, and cleaning, none of which affected vegetative states.

Management regimes were developed at the Stevensville Ranger District office and focus primarily on high-density stands consisting of Douglas-fir, ponderosa pine and lodgepole pine with specific emphasis on lodgepole pine. Within these management regimes, the treatment intensity ranged from light to a very heavy harvest. Fire regimes allowed for treatment across all areas and provided a range of treatment intensity Management regimes include: commercial thin; improvement cut; prescribed burn; prethin only; prethin, commercial thin, and repeat burn; commercial thin and repeat burn; and commercial thin then seedtree and burn, and repeat burn.

MAGIS was set up to capture the effects of the following variables: prescribed burn acres and costs; improvement cut acres and costs; prethin acres and costs; commercial thin acres and costs; seedtree acres and costs; no action acres; acres by EAR and CAR (three levels); submerchantable and sawlog volume; and total costs by period, PNV for each of the five periods, and discounted net costs by period. These effects functions enabled us to compare each of the management regimes in terms of objectives and accomplishments.

We used the Northern Region Cohesive Strategy Team's risk assessments (i.e., communities at risk (CAR) and ecosystems at risk (EAR)) to define objective functions in MAGIS (USDA Forest Service 2003). Specifically, we integrated the risk rule sets into MAGIS so that risk attributes change dynamically with changes in vegetation over time. Vegetative states are modeled using succession and are based on the Region 1 west side zones, also used in SIMPPLLE (SIMulating Processes and Patterns at Landscape scaLEs[8]) Definitions for EAR and CAR are presented below as they are defined on the Internet.[9]

Ecosystems At Risk (EAR)

Estimating the relative risk of ecosystems from wildland fire requires an assessment of the likelihood of fire occurrence; and likely fire effects to an ecosystem should it catch fire. A spatial of ignition probability was derived from 20-years of fire data by interpolating between known fire locations and counting the of fires within a 4-km2 neighborhood. Ignitions were then classified [into]5 classes ranging from low to high.

Fire-regime condition class is an index of the of the current condition from the historical fire regime. Consequently it is derived from the historical fire regime and an estimate of the fire severity if a fire occurred. Fire-regime condition class is as a proxy for the probability of severe fire effects (e.g., the of key ecosystem components - soil, vegetation structure, species; alteration of key ecosystem processes - nutrient cycles, hydrologic regimes. Consequently, fire-regime condition class is an index of risk to the of many components (e.g., water quality, fish status, wildlife habitats, etc.).

Ignition probability was integrated with fire-condition class to derive ecosystems-at-risk; the likelihood that components will be lost if a wildland fire occurred.

8 http://www.fs.fed.us/rm/missoula/4151/SIMPPLLE
9 http://www.fs.fed.us/r1/cohesive_strategy/sitemapfr.htm.

Communities At Risk (CAR)

The top priority of the National Fire Plan, FS-Cohesive Strategy and the Western Governors' 10-Year Comprehensive Strategy Plan is undoubtedly to reduce the threats of wildland fire to wildland-urban interface. The relative risk of communities to fire requires the consideration of 3 factors: (1) the of fire occurrence; (2) the likely fire behavior should a fire occur; and (3) human settlement patterns. Therefore, the ignition probability, fire behavior, and population density spatial themes were to estimate the relative risk of the wildland-urban interface wildland fires.

We will use EAR and CAR as the basis for our models so that our assumptions and sensitivity analysis will be based on realistic fire management goals that are consistent with the National Fire Plan.

Scenarios

Our primary goal was to map a landscape in the Bitterroot Valley that could be manipulated by fuels treatments using MAGIS to (i) minimize areas at risk, or (ii) maximize PNV, for given sets of constraints including treatment timing, budget levels, and acres treated. Specifically, we addressed how targeted temporal goals affect allocation and cost; how the budget affects accomplishments and allocation between objectives; and, how targeted acres affect costs and objectives.

To address these research questions, we developed a set of scenarios and decision rules as follows as listed in Table 2. We pursued two general objectives: to minimize acres classed as EAR or CAR, and to maximize present net value (PNV).

Table 2: Treatment Scenarios

Scenario	Objective	Constraints
1a	No Action	none
2a	Minimize EAR 3-1	none
2b	Minimize CAR 3-1	none
2c	Minimize EAR 3-1	CAR 3-1 = 4,300 Acres
2d	Minimize CAR 3-1	EAR 3-1 = 18,500 Acres
3	Minimize EAR 3-1	CAR 3-1 = 4,300 Acres, Budget = $1M
4a	Minimize EAR 3-2	EAR 3-1 = 20000 Acres
4b	Minimize EAR 3-3	EAR 3-1 = 20000 Acres, EAR 3-2 = 31,000
4c	Minimize EAR 3-4	EAR 3-1 = 20,000, EAR 3-2 = 31,000, EAR 3-3 = 30,000 Acres
4d	Minimize EAR 3-1	EAR 3-2 = 28,000, EAR 3-3 = 30,000, EAR 3-4 = 32,000, EAR 3-5 = 32,000 Acres
4e	Minimize EAR 3-5	EAR 3-1 = 20,000, EAR 3-2 = 31,000, EAR 3-3 = 30,000, EAR 3-4 = 36,000 Acres
5a	Minimize CAR 3-2	CAR 3-1 = 5,000 Acres
5b	Minimize CAR 3-3	CAR 3-1 = 5,000, CAR 3-2 = 10,000 Acres.
5c	Minimize CAR 3-4	CAR 3-1 = 5,000, CAR 3-2 = 10,000, CAR 3-3= 10,000 Acres.
5d	Minimize CAR 3-5	CAR 3-1 = 5,000, CAR 3-2 = 10,000, CAR 3-3= 10,000, CAR 3-4 = 11,000 Acres.
6	Minimize EAR 2-1	EAR 3-1 = 18,500 Acres
7a	Maximize PNV	CAR 3-1 = 4,300, EAR 3-1 = 18,000 Acres
7b	Maximize PNV	CAR 3-1 = 4,300, EAR 3-1 = 18,000 Acres, Budget = $1M
8	Maximize PNV	Budget = $1M per decade, EAR 3-1 = 18,000 Acres.

Scenario 1 was no action which was run over five decades. No treatments were assigned resulting in a basis for which to compare all other scenarios. The objectives for scenarios 2a and 2b were to minimize the number of acres classified as EAR 3 in decade one and CAR 3 in decade one. Based on the results from 2a and 2b, constraints were introduced for scenarios 2c and 2d. Scenario 2c minimized acres classed as EAR 3 in decade 1 holding acres classed as CAR 3 in decade one at equal to or less than 4,300 acres. Similarly, scenario 2d minimized CAR 3 in decade one while constraining acres of EAR 3 in decade 1 to equal to or less than 18,500. Scenario 3 is similar to 2c but with a budget constraint of less than or equal to $1M for the five decades.

Scenarios 4a-e minimized EAR in different decades and were constrained variably by achieving EAR acreage targets. There were no budget constraints introduced. Similarly scenarios 5a-d minimized CAR in different decades and were constrained by minimum CAR acreage achievements. Scenario 6 minimized EAR 2 in decade one while constraining EAR 3 in decade one to equal to or less than 18,500 acres. The

The objective for scenarios 7 and 8 were to maximize the PNV over the 50-year period. Scenario 7a and 7b both restricted EAR 3 and CAR 3 in decade one, however, 7b was further constrained by a budget of less than or equal to $1M for the simulation period. Scenario 8 was less restrictive allowing the budget to be $1M/decade. The only acreage constraint was EAR 3 in decade one of 18,000 acres.

Treatment methods were predicated on condition class. For example, mechanical treatment methods were first used for ecosystems classed as condition class three (CC3) prior to prescribed burning. MAGIS output lists acres treated by method, which is available from the authors upon request.

RESULTS

Simulation results are presented in Table 3 by scenario and objective. Present net value and total cost are listed in thousands of dollars; saw log (SL) volume is measured as ccf and sub-merchantable (SM) volume is measured in tons; parentheses indicate negative values.

Table 3: Simulation Results

Scenario	Objective	PNV $000	Cost $000	SL (ccf)	SM (ton)	Constraints
1a	No Action	n/a	n/a			none
2a	Minimize EAR 3-1	13,349	4,303	1,411,524	101,191	none
2b	Minimize CAR 3-1	(378)	378	0	0	none
2c	Minimize EAR 3-1	12,166	4,294,	226,077	95,463	CAR 3-1 = 4,300 Acres
2d	Minimize CAR 3-1	(10,077)	1,970	11,293	6,390	EAR 3-1 = 18,500 Acres
3a	Minimize EAR 3-1	(821)	821	0	0	CAR 3-1 = 4,300 Acres, Budget = $1M
4a	Minimize EAR 3-2	603	2,106	29,738	14,984	EAR 3-1 = 20000 Acres
4b	Minimize EAR 3-3	2017	6,863	252,086	178,227	EAR 3-1 = 20000 Acres, EAR 3-2 = 31,000
4c	Minimize EAR 3-4	28,490	6,710	420,514	172,737	EAR 3-1 = 20,000, EAR 3-2 = 31,000, EAR 3-3 = 30,000 Acres
4d	Minimize EAR 3-1	29,780	6,596	240,958	170,007	EAR 3-2 = 28,000, EAR 3-3 = 30,000, EAR 3-4 = 32,000, EAR 3-5 = 32,000 Acres

4e	Minimize EAR 3-5	29,699	6,899	441,348	183,842	EAR 3-1 = 20,000, EAR 3-2 = 31,000, EAR 3-3 = 30,000, EAR 3-4 = 36,000 Acres
5a	Minimize CAR 3-2	(376)	376	0	0	CAR 3-1 = 5,000 Acres
5b	Minimize CAR 3-3	(415)	415	0	0	CAR 3-1 = 5,000, CAR 3-2 = 10,000 Acres.
5c	Minimize CAR 3-4	(397)	397	0	0	CAR 3-1 = 5,000, CAR 3-2 = 10,000, CAR 3-3= 10,000 Acres.
5d	Minimize CAR 3-5	(395)	395	0	0	CAR 3-1 = 5,000, CAR 3-2 = 10,000, CAR 3-3= 10,000, CAR 3-4 = 11,000 Acres.
6a	Minimize EAR 2-1	7,406	5,940	96,05	1,595,164	EAR 3-1 = 18,500 Acres
7a	Maximize PNV	97,438	18,969	1,783,581	826,339	CAR 3-1 = 4,300, EAR 3-1 = 18,000 Acres
7b	Maximize PNV	(821)	821	0	0	CAR 3-1 = 4,300, EAR 3-1 = 18,000 Acres, Budget = $1M
8a	Maximize PNV	3,781	1,493	36,798	26,320	Budget = $1M per decade, EAR 3-1 = 38,000 Acres.

The no action alternative resulted in zero costs and revenues as a result of no treatments in any areas. We used this alternative as a benchmark to calculate the number of acres in each of the CAR and EAR categories (1-3) over five decades. The majority of acres in the WUI were designated as CAR 2 at 123,334 followed by Car 3 (55,563) and CAR 1 (22,597). The majority of wildland acres were classed as EAR 1 (780,660) followed by EAR 2 and EAR 3 (567,143 and 232,915).

Addressing the WUI first, any objective to minimize car by treating acres classed as CAR 3 resulted in a negative PNV. This was likely due to the lack of timber harvested resulting in little or no revenue. The only exception is scenario 2d which was constrained by minimum acreage requirements for EAR 3. While all treatments were available on all acres regardless of ownership, CAR treatments selected by MAGIS were net cost activities.[10]

The three least-cost scenarios were 5a which aimed to reduce high risk WUI acres in the second decade while forcing the solution to have no more than 5,000 acres in the first decade. This objective did not have a budget constraint and resulted in a cost of $376 K. The second least-cost alternative was 2b which minimized high risk in the first decade at a cost of $378 K. The increase in cost is a result of treating higher risk acres sooner in the five-decade period. The third alternative was 5d which minimize high risk at the end of the planning period while forcing maximum acceptable acres in the previous decades. Again there was no budget constraint and costs were $395 K over the simulation period.

The scenarios that achieved the greatest reduction in acres classed as CAR 3 were 5c, 5d, and 5b. The first scenario resulting in no increase in CAR 1 in any decade, yet a reduction of 14.6% of acres in CAR 3 throughout the planning period, and an increase by 6.6% in CAR 2 acres. The greatest change occurred in the first decade with an increase in CAR 2 by 21.9% and a reduction in CAR 3 by 49.14%. The results for scenarios d and b were similar with the exception of timing; treatments under 5b increased CAR 2 in the third decade rather than the second. The overall result is a small increase in CAR 2 acres (5.94%) and a slight decrease in CAR 3 acres (13.19%). None of these scenarios resulted in positive PNV.

Reducing ecosystem risk (EAR) under a CAR management objective was best achieved by scenario 2d resulting in a decrease in EAR 3 of 17% and an increase in EAR 1 of 5%

[10] Only three treatments resulted in revenue: improvement cut, commercial thin, and seed tree cut.

with no change in EAR 2. This solution was constrained by forcing EAR 3-1 to be less than 18,500 acres. As a result, this scenario had the greatest loss of $10M over five decades.

With respect to ecosystem objectives all scenarios that minimized EAR resulted in a positive NPV with the exception of 3a. The least-cost scenario that had a positive PNV was 2d at a cost of $2 M with a PNV of $603 K. The effects were an increase in EAR 1 of 5%, no change in EAR 2, and a decrease in EAR 3 of 17% over the simulation period. Most scenarios resulted in a positive PNV with the exception of 3a. The four most profitable were 4d (PNV $29.8M, cost of $6.5M), 4e (PNV $29.7M, cost of $6.9M), 4c (PNV $29.0M, cost of $6.9M) and 4b (PNV $28.4M, cost of $6.7 M). Each of these scenarios resulted in an increase in EAR 1 of 10%, an increase in EAR 2 of 1% and a decrease of EAR 3 of 35% with the exception of 4b resulting in a decrease of EAR 3 of 33%. The scenario that resulted in the greatest achievement in the WUI given the ecosystem objective was 2c with a decrease in EAR 3 of 17% and CAR 3 of 11%. This result is also cost effective given costs of $4.9M with PNV of $12M over the five decades.

We turn now to the maximization strategies, 7a, 7b and 8. Scenario 7a maximized PNV under two constraints: CAR 3 in decade on of less than or equal to 4,300 acres, and EAR 3 in decade 1 less than or equal to 18,000 acres. The result was PNV of $97M at a cost of $18M. Using scenario 7b, we introduced a budget constraint of less than or equal to $1M/decade. We also retained the constraints on CAR and EAR. This resulted in a negative PNV of $18M. Finally, we maximized PNV in scenario 8 while dropping the CAR constraint and relaxing the EAR constraint to less than or equal to 38,000 acres. The final result was a positive PNV of $3.7M and costs of 1.5M. The greatest impact on EAR resulted form 7a with an average increase in EAR 1 of 15%, a decrease in EAR 2 of 7% and a decrease in EAR 3 of 33%. The greatest impact on CAR not surprisingly resulted from 7b with a decrease in CAR 3 of 18%, and an increase in CAR 2 of 2% and no change in CAR 1. A summary of acreage changes is given in Table 4.

Table 4: Acres in EAR and CAR after treatment - % change.

	Average acres	% change from no action by scenario				
Risk Category	No Action	2a	2b	2c	2d	3a
CAR 1	4519.4	1%	0%	1%	1%	0%
CAR 2	24666.8	2%	5%	5%	5%	5%
CAR 3	11112.6	-6%	-11%	-11%	-11%	11%
EAR 1	150132	5%	1%	5%	5%	2%
EAR 2	113428.6	0%	0%	0%	0%	0%
EAR 3	46583 0	-17%	-1%	-17%	-17%	-6%
Average acres	No Action	4a	4b	4c	4d	4e
CAR 1	4519.4	1%	1%	1%	1%	1%
CAR 2	24666.8	5%	3%	3%	3%	3%
CAR 3	11112.6	-6%	-7%	-7%	-7%	-7%
EAR 1	150132	5%	10%	10%	10%	10%
EAR 2	113428.6	0%	1%	1%	1%	1%
EAR 3	46583 0	-17%	-33%	-35%	-35%	-35%
Average acres	No Action	5a	5b	5c	5d	6a
CAR 1	4519.4	0%	0%	0%	0%	42%
CAR 2	24666.8	5%	6%	7%	5%	-3%
CAR 3	11112.6	-11%	-13%	-15%	-14%	-10%

EAR 1	150132	1%	1%	1%	1%	11%
EAR 2	113428.6	0%	-1%	-1%	-1%	-8%
EAR 3	46583	-2%	-2%	-2%	-2%	-17%
	0					

Average acres	No Action	7a	7b	8
CAR 1	4519.4	1%	0%	1%
CAR 2	24666.8	5%	2%	3%
CAR 3	11112.6	-11%	-18%	-6%
EAR 1	150132	15%	2%	5%
EAR 2	113428.6	-7%	0%	0%
EAR 3	46583	-33%	-13%	-18%

DISCUSSION

Given the three objectives, it is apparent that minimizing risk in the WUI (Min CAR 3) is not cost effective, when considered in a landscape management context. However, minimizing ecosystem risk most often results in outcomes having a positive NPV. Furthermore, scenarios that targeted a reduction of ecosystem risk (Min EAR 3) resulted in decreases in CAR 3 (scenarios 4, 7a, 8), thereby accomplishing both objectives. The strategy that best reduced risk in both EAR and CAR was 7a where we maximized PNV although this was achieved at significant budget levels.

Our results also raise questions regarding cost effectiveness and fiscal responsibility both from the agency and homeowner perspective. Focusing fuels management efforts on ecosystems that are considered to be outside the range of historic variability may be the most efficient and ecologically best alternative. Strategies that are focused on the WUI however, result in little change with respect to ecosystem risk in non-WUI areas and are not feasible. Clearly there is a significant opportunity cost of treating the WUI. Furthermore, focusing on reducing ecosystem risks related to fire provides an opportunity to revitalize the timber industry by making available saw timber over a 50-year planning horizon. While this may not be realistic from an administrative perspective given 10-year forest plans and actual planning and revision horizons, this may accomplish ecological goals more cost effectively.

The results also give rise to serious questions regarding funding for fuels management applications directed at reducing risk in the WUI. These strategies result in net financial costs and ecological opportunity costs largely borne by the public, while the benefits from WUI fuels treatments accrue to residents in those areas. Essentially, the public is supporting private home owners adjacent to public lands. While this issue is outside of the scope of this paper, it gives rise to questions surrounding who should pay for fuels treatments, protection incentives, and insurance.

This work provides a guide to examine implications of different fuels management goals objectives. While the solutions are not definitive, they enable forest and fire planners to get a better understanding. Our results provide fire and forest managers with much needed information regarding the feasibility of fuels treatment methods over time. Using an array of treatment scenarios we were able to assess changes in costs and accomplishments, and to identify the potential success of fire management programs aimed to reduce risk in the wildland-urban interface, or to restore ecosystems, or some combination. Our findings will also be useful to policy makers for guidelines to develop realistic fire management policy regarding annual accomplishments and outcomes.

REFERENCES

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press: Washington, D.C. 493 pp.

Arno, S.F. 2000. Chapter five: Fire in Western forest ecosystems. In: Brown, J.K.; Smith J.K., eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: US Department of Agriculture, Forest Service, Rocky Mountain Research Station: 97-120.

Arno, S.F.; Petersen, T.D. 1983. Variation in estimates of fire intervals: A closer look at fire history on the Bitterroot National Forest. Research Paper INT-301. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 pp.

Arno, S.F.; Scott, J.H.; Hartwell, M.G. 1995. Age-class structure of old growth ponderosa pine/Douglas-fir stands and its relationship to fire history. Research paper INT-RP-481. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Research Station. 25 pp.

Baker, W.L. 1993. Spatially heterogeneous multi-scale response of landscapes to fire suppression. Oikos 66, 66-71.

Brown, J.K.; Arno, S.F.; Barrett S.W.; Menakis, J.P. 1994. Comparing the prescribed natural fire program with presettlement fires in the Selway-Bitterroot Wilderness. International Journal of Wildland Fire 4, 157-168.

Chew, J.D. 1995. Development of a system for simulating vegetative patterns and processes at landscape scales. Ph.D. dissertation. University of Montana, Missoula, MT. 182 pp.

Chew, J.D.; Moeller, K.; Stalling C.; Bella; E.M.; Ahl, R.S. 2002. User's Guide for SIMPPLLE, version 2.2. Proposed Gen. Tech. Rep. RMRS-GTR-xxx. US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 222 pp.

ESRI Inc. 2001. ArcGIS, version 8.2. Environmental Systems Research Institute, Inc. Redlands, CA. USA.

Hartwell, M.G. 1997. Comparing historic and present conifer species compositions and structures on forested landscapes of the Bitterroot Front.

Jones, J. G.; Chew, J. D; Zuuring, H R. 1999. Applying simulation and optimization to plan fuel treatments at landscape scales. In: Gonzalez-Caban, Armando; Omi, Philip N., tech. coords. Gen. Tech. Rep. PSW-GTR-173. Proceedings of the Symposium on Fire Economics Planning, and Policy: Bottom Lines; 1999 April 5-9; San Diego, CA. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station: 229-336.

Jones, J.L.; Barrett S.W.; Berglund, D. 2002. Modeling historical and current fire regimes for major vegetation types in northern Idaho and western Montana: A first approximation. Office report on file, Planning Division, USDA Forest Service, Flathead National Forest, Kalispell, MT. 27 pp.

Keifer, M.; Caprio, A.C.; Lineback, P.; Folger, K. 2000. Incorporating a GIS model of ecological need into fire management planning. Pages 122-129 in Neuenschwander, L.G.

and Ryan, K.C., technical eds. Proceedings of the Joint Fire Science Conference and Workshop, Volume 1, June 15-17 1999, Boise, ID.

Landres, P.B.; Morgan, P.; Swanson, F.J. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications 9(4), 1179-1188.

Laverty, L., and Jerry Williams. 2000. Protecting people and sustaining resources in fire-adapted ecosystem: a cohesive strategy. Washing ton D.C., General Accounting Office: 85.

Long, D.G. 1998. Mapping historical fire regimes in northern Rocky Mountain landscapes. Thesis. University of Idaho, Moscow, Idaho. 63 pp.

Miller, C.; Landres, P.B.; Alaback, P.B. 2000. Evaluating risks and benefits of wildland fire at landscape scales. Pages 78-87 in Neuenschwander, L.G. and Ryan, K.C., technical eds. Proceedings of the Joint Fire Science Conference and Workshop, Volume 1, June 15-17 1999, Boise, ID.

Sampson, N.; Atkinson, D.; Lewis, J. eds. 2000. Mapping wildfire hazards and risks. The Haworth Press, Inc.

Schmidt, K.M.; Menakis, J.P.; Hardy, C.C.; Hann, W.J.; Bunnell, D.L. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station, 41pp. + CD.

US Department of Agriculture, Forest Service, Northern Region Cohesive Strategy Team. 2003. Fire management plan. http://www.fs.fed.us/r1/cohesive_strategy/contactfr.htm. Flathead National Forest, 1935 3rd Ave. East. Kalispell, MT 59901.

US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2002, September). Fire Effects Information System, [Online]. Available: http://www.fs.fed.us/database/feis/ [Accessed September 2002].

US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 2003. Software and land management planning. http://www.fs.fed.us/rm/econ/magis/ accessed February 25, 2004.

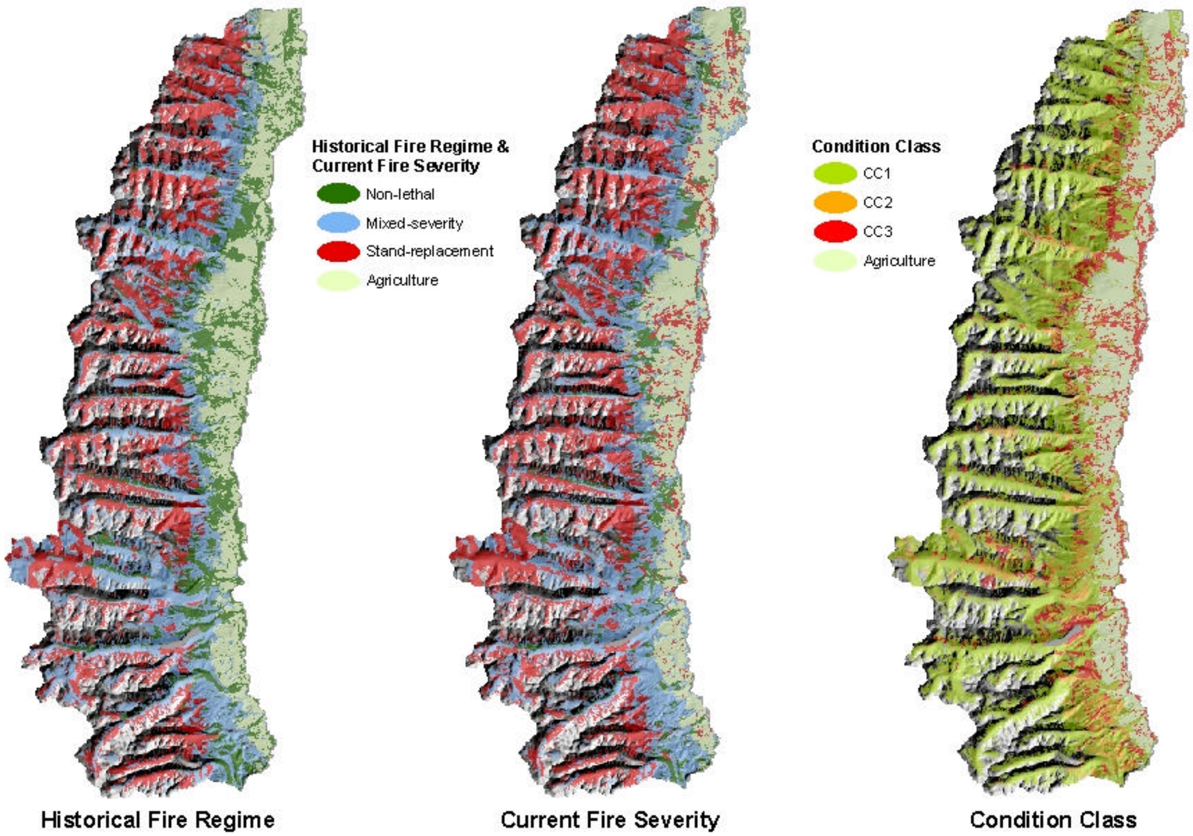
US Department of the Interior and US Department of Agriculture. 2001. Review and update of the 1995 federal wildland fire management policy. Bureau of Land Management, Boise, ID.

WSAL. 2000. FireRisk: A fuels, fire, fire regime database. Version 1.0. Prepared for the USDA Forest Service, Northern Region by Wildlife Spatial Analysis Lab, Montana Cooperative Wildlife Research Unit, The University of Montana, Missoula, MT 59812.

APPENDIX A: BITTERROOT FRONT MAP

Historical Fire Regime, Current Fire Severity, and Condition Class of Bitterroot Front.

Modeling rules adapted from Jones et al. (2002) and applied to Bitterroot Front polygon coverage (acquired from RMRS Forestry Sciences Lab 2002)



APPENDIX B: TRAVEL COST/CVM RECREATION SURVEY FOR MONTANA

FOREST FIRES AND YOUR RECREATION USE

Dr. Hayley Hesseln
School of Forestry
University of Montana
Missoula, MT 59812

School of Forestry, The University of Montana

We would like to ask some questions about the trip and recreation area where you were given this survey.

1. Name of Trail/Area where you received survey?

____

2. What features of this recreation area are important to you?

The next few questions ask you to rate the importance of different features of this recreation area and trails. Circle the one answer that best reflects how important each feature is in your decision to visit this area.

	Not Important	Somewhat Important	Important	Very Important
Scenic Vistas	1	2	3	4
Forested Areas	1	2	3	4
Recreation Facilities (parking, restrooms)	1	2	3	4
Opportunity to view wildlife	1	2	3	4
Road Access	1	2	3	4
Wildflowers	1	2	3	4
Location	1	2	3	4

3. What was the primary or main recreation activity you participated in during this trip to this area where you received the survey? Please choose one.

ÿCamping
ÿ Hiking
ÿ Picnicking
ÿ Swimming
ÿ Fishing
ÿ Backpacking
ÿ Mountain Biking
ÿ ATV use
ÿ Hunting
ÿ Wildlife Viewing
ÿ Sightseeing
ÿ Horseback Riding
ÿ Mushroom Gathering
ÿ Berry Picking
ÿ Mountain or Rock Climbing

ÿ Other, please list____

4. How long was your visit to this site on this trip? ______hours ______days

5. How far did you hike/ride today? ______miles

6. Would you have normally worked for pay today? ______Yes ______No

7. Was visiting this site the (check one):
__ Sole or major purpose of your trip from home
__ One of many equally important reasons of a longer trip
__ Just a minor stop or spur-of-the-moment decision to stop

If your visit to this site was a minor stop, please answer Questions #8 and #9, with the EXTRA time and EXTRA distance required to visit this site.

8. About how much time (one way) did it take you to travel from your home to the site where you were contacted? _______Hours _______Minutes

9. About how far is it one-way, from your home to this site? _______Miles

10. How many people are in your group? # of people ___________

11. What was **your share** of the costs for this trip?

Gasoline/car expenses $_____

Camp fees/lodging $_____

Supplies/Miscellaneous $_____

12. If the cost of visiting this site today had been $______ higher would you have made this trip to this site today? (Circle one) Yes No

The next few questions ask about the number of visits to this area.

13. In 1999, about how many trips did you make to this particular trail head or area where you were contacted?

	May 99	June 99	July 99	August 99	September 99
Trips Taken	_______	_______	_______	_______	_______

14. In 2000, how many trips have you taken to this particular trailhead or area where you were contacted? Also fill in how many trips you plan to take to this site during the remaining months of the season?

	May 00	June 00	July 00	August 00	September 00
Trips Planned	_______	_______	_______	_______	_______
Trips Taken	_______	_______	_______	_______	_______

15. The cost of recreation changes with gas prices and equipment costs. If the cost of visiting this site had been $_____ per trip higher tell us how many trips you would take in each month?

	May 00	June 00	July 00	August 00	September 00
Trips you would take?	______	_______	_______	_______	_______

1. The picture below displays what a portion of this trail would be like if it had been burned by a recent forest fire. Please take a few moments to look at the photo below.

Suppose that at the beginning of the season you read that 50% of the area along this trail would have been burned by a forest fire such as shown in the photo above.

Would this have affected the number of trips you would take to this area each month?

Please write down what your trips would have been or you would have taken to this area if it had been burned as shown in the photo for half the trail you visited.

	May	June	July	Aug.	Sept.
Trips you would take	_______	_______	_______	_______	_______

Any comments on your answer to this question?

____

____

____

____

2. The picture below displays what a portion of this trail would be like if it had been affected by a small forest fire. Please take a few moments to look at the photo below.

Suppose that at the beginning of the season you read that 50% of the area along this trail would be as shown in this photo.

Would this have affected the number of trips you would take to this area each month?

Please write down what your trips would have been or you would have taken to this area if the trail you visited looked like the photo.

	May	June	July	Aug.	Sept.
Trips you would take	_______	_______	_______	_______	_______

Any comments on your answer to this question?

____

____

____

____

3. The picture below displays what a portion of this trail would be like if it had been affected by a forest fire many years ago. Please take a few moments to look at the photo below.

Suppose that at the beginning of the season you read that 50% of the area along this trail would be as shown in this photo.

Would this have affected the number of trips you would take to this area each month?

Please write down what your trips would have been or you would have taken to this area if the trail you visited looked like the photo.

	May	June	July	Aug.	Sept.
Trips you would take	_______	_______	_______	_______	_______

Any comments on your answer to this question?

____

____

____

____

About You

These last few questions will help us in evaluating how well our sample represents visitors.
YOUR ANSWERS ARE STRICTLY CONFIDENTIAL & WILL ONLY BE USED FOR THE ANALYSIS OF THIS STUDY. YOU WILL NOT BE IDENTIFIED IN ANY WAY.

1. Are you ________Male ________Female

2. What is your age: ________Years

3. Are you retired? ________Yes ________No

4. What is your zip code? ____________________________

5. How long have you lived in this zip code? ________Years

6. Are you a member of a conservation or environmental organization?

________Yes ________No

7. Highest level of formal schooling? (Please circle one)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
(Elementary) (Jr.High) (High School) (College or or Technical School) Graduate or Professional School)

8. Do you work outside the home? ________Yes ________No

9. When you recreate, do you almost always go on weekends, holidays, vacations or other non-work days?
________Yes ________No

10. How many weeks of paid vacation do you receive each year? ________________number of weeks

11. How many members in your household? ________people

12. How many contribute to paying the household expenses? ________people

13. Including these people, approximately what was your household income from all sources (before taxes) last year?

__less than $10,000 __$40,000 to $49,999 __$80,000 to $89,999
__$10,000 to $19,999 __$50,000 to $59,999 __$90,000 to $99,999
__$20,000 to $29,999 __$60,000 to $69,999 __$100,000 to $149,999
__$30,000 to $39,999 __$70,000 to $79,999 __ over $150,000

Thank you for completing the survey!

If you have any additional thoughts on forest or recreation management, please feel free to write them down on the back cover. When you are finished, please put the survey in our **stamped** return envelope and mail it back to us.

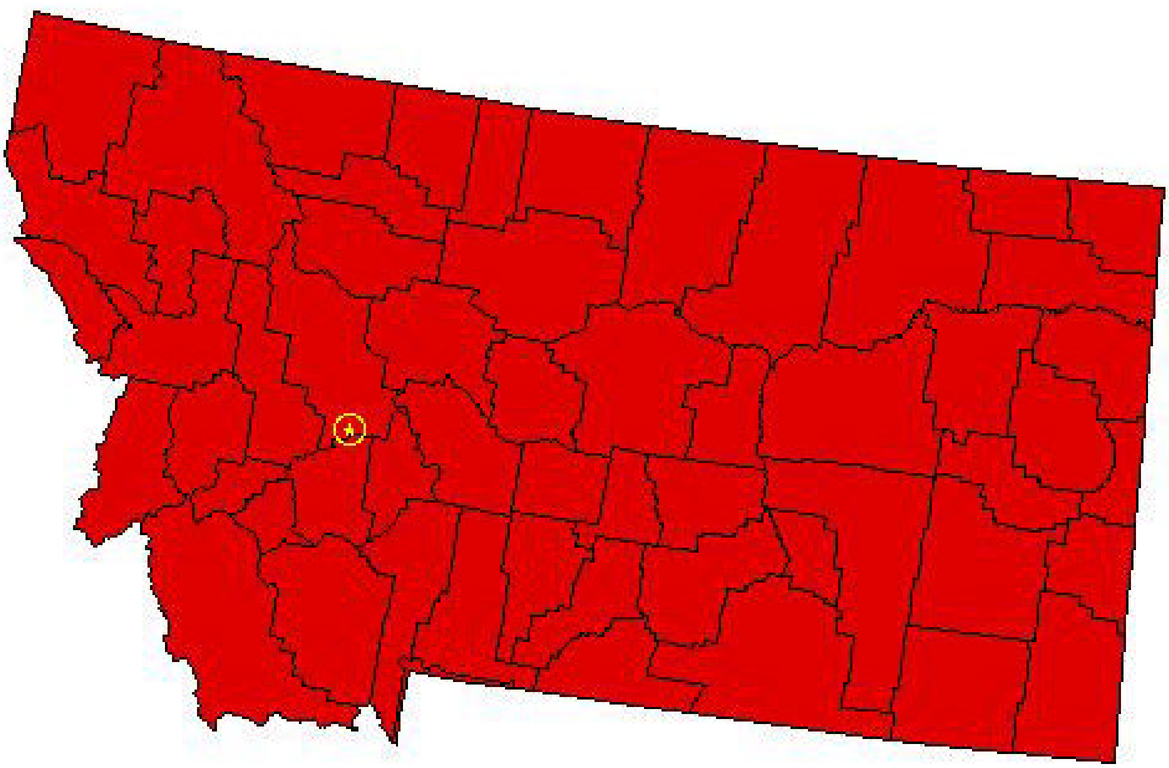
THANK YOU FOR COMPLETING THE SURVEY!

Additional comments welcome. Please use the space below.

APPENDIX C: CVM SURVEY

CVM Survey for California English and Spanish versions available upon request.

EXPANDED MONTANA FIRE MANAGEMENT PROGRAM



What do you think?

Expanded Montana Fire Management Program

WHAT DO YOU THINK?

Expanded Montana Fire Management Program

Definitions

Fire in Montana is an ever-present and natural part of the landscape. Your views on this topic are very important to federal, state and tribal fire managers in Montana as managers decide how to protect houses and preserve Montana's forests and wildlife in the future. Your participation in this survey is greatly appreciated. Please read the booklet over prior to your scheduled phone interview. This will speed up your interview. Thanks.

Before you answer this survey we want to familiarize you with the following fire management terms:

Prescribed fire or prescribed burn: A fire purposely and carefully set in a designated area by fire management personnel to accomplish one or more specific objectives such as removal of underbrush and dead wood to reduce available fire fuel and increase the ability to control future wildfires.

Wildfire: A fire started by human activities or a lightning strike. A wildfire, occurring under unfavorable weather conditions, can be difficult to control due to high intensity and/or rapid rate of spread.

Fire management: Consists of the following four activities: fire prevention, prescribed burning, fire detection and fire suppression.

Structural fire: A building or house that is on fire.

Health standard: The minimum level of air quality, which the Environmental Protection Agency considers to be healthy.

Before beginning let me tell you that currently the federal, state and tribal agencies in Montana have in place a fire management program that both controls wildfires and authorizes prescribed fire on federal, state and tribal forest and rangelands.

Expanded Montana Fire Management Program

Description

What is the current problem?

An attempt to keep fire from burning forest and rangelands over the past several decades has helped lead to an unnatural buildup of wildfire fuel in the form of brush, dead branches, logs and pine needles on the forest floor. Generally, resulting wildfires burn very hotly. As shown in Figure 1, the flames from these wildfires can burn all the way to the top of tall trees and houses and spread very fast making these wildfires difficult to put out. Under very dry conditions these high intensity wildfires burn nearly everything, frequently causing high levels of air pollution.

WILDFIRE

Fire Spread ½ - 2 miles/ hour, flame height 30-60 feet **Figure 1**

What is a solution?

One long-term solution to the problems caused by unnatural buildup of wildfire fuel is to restore a fire cycle similar to that which existed before active fire management in Montana. This means having fire professionals periodically set prescribed fires to clear the forest floor of the excess brush, dead branches and pine needles.

How does it work?

Prescribed fires are easier to manage than wildfires since, as shown in Figure 2, prescribed fires do not burn as intensely (rate of spread and flame height are much lower in Figure 2) and they can be directed away from structures. While prescribed fires do result in a temporary increase in air pollution, they generally produce far less air pollution than would a wildfire on the same acreage.

Most importantly, fire professionals reviewing the 2000 Montana wildfires suggested that areas that had been previously prescribed burned, tended to have lower flame lengths and slower rates of spread. This slower rate of spread and lower flame length often made it possible to contain wildfires and protect structures which would have otherwise been lost.

Scientific studies indicate that under normal weather conditions prescribed burning reduces the number of acres that would burn each year from wildfires.

PRESCRIBED BURNING

Fire spread 60 – 120 feet/hour; flame height 4-8 feet. Figure 2

What about air quality?

By timing prescribed fires with favorable weather and wind conditions, smoke can be directed away from the majority of the population.

Prescribed fires generally produce less smoke than wildfires, and wildfire smoke can exceed health standards.

What is the proposed program?

Foresters, fire professionals and scientists are suggesting an expanded program of prescribed burning for Montana's 30 million acres of federal, state, tribal and private forest and rangelands to reduce the extent and damages of wildfires. Under the current program, about 37,000 acres are prescribed burned each year.

To reduce the size and damage from wildfires, and to improve the safety of both the public and firefighters, it is recommended that 50,000 acres be prescribed burned each year.

Features of the Program

The new initiative for prescribed burning is believed by foresters and fire professional to be the minimum sufficient to:

- Restore a fire cycle similar to that which existed historically in Montana by increasing the frequency of low intensity fires over time, and reduce the threat of high intensity wildfires that could completely burn the forest to the ground and spread to any nearby houses or structures.

- Benefit many of Montana's native plant and wildlife species. For example, prescribed fire allows sunlight to reach the forest floor, which stimulates the growth of many types of flowers and shrubs thereby providing food sources for wildlife.

- Reduce the chances of wildfire smoke exceeding air quality health standards.

- Control forest disease.

- Protect wildlife due to the slow moving nature of prescribed burns, which allows wild animals to find refuge in damp areas or migrate out of the area.

Results of the Program

If the Prescribed Burning Program is expanded in Montana, it is expected to reduce the number of acres of high intensity wildfire and houses lost to wildfires. Currently, in a typical year approximately 1,900 wildfires burn approximately 140,000 acres and destroy about 20 houses in Montana. If the Expanded Prescribed Burning Program were implemented, it is expected to reduce the number of acres burned by wildfires from approximately 140,000 to about 105,000 acres for a total reduction of 35,000 acres. This represents a 25% reduction in acres burned by wildfire. The number of houses destroyed by future wildfires is expected to be reduced from an average of 20 a year to about 8.

Given the discussion above, do you think forest managers should or should not undertake this expanded program of prescribed burning underbrush and debris in Montana's forests?

1. Should
2. Should not
3. Don't know

Costs of Increased Prescribed Burning in Montana

While prescribed burning programs such as described above have proven effective at reducing the extent and severity of wildfire, there is not sufficient funding currently available to carry out such programs on all of the 30 million acres of federal, state, tribal, and private forest and rangelands in Montana.

Who would fund this program?

Montana is considering using some state revenue as matching funds to help federal, state, tribal and private individuals finance fire prevention programs. If a majority of residents vote to pay the county share of this program, the Expanded Montana Prescribed Burning Program would be implemented in your county and other counties in Montana on federal, state, tribal and private forest and rangelands.

Funding of the Expanded Montana Prescribed Burning Program would require that all users of Montana's forest and rangelands, such as timber companies, recreation visitors, and Montana households pay the additional cost of this program. If this Expanded Prescribed Burning Program were to be implemented, by law, the money would be deposited in a separate Montana Prescribed Burning Fund, which could only be used to carry out the Expanded Prescribed Burning Program described above. A citizen advisory board would review the expenditures from the fund annually.

Results of the Program

If the Expanded Prescribed Burning Program was undertaken it is expected to reduce the number of acres of wildfires from the current average of approximately 140,000 acres each year to about 105,000 acres, for a 25% reduction. The number of houses destroyed by wildfires is expected to be reduced from an average of 20 a year to about 8.

Your chance to vote

Your share of the Expanded Prescribed Burning Program would cost your household $_______ a year. If the Expanded Prescribed Burning Program were on the next ballot would you vote?

1. In favor
2. Against

Alternative Method in the Montana Fire Management Program

Mechanical Fire Fuels reduction Program

Another approach to reducing the buildup of fuels in the forest is to "mow" or mechanically chip the low- and medium-height trees and bushes into mulch. This is especially effective at lowering the height of the vegetation, which reduces the ability of fire to climb from the ground to the top or crown of the trees. In addition, mechanical "mowing" slows the growth of new vegetation with the layer of mulch acting as a barrier.

Mowing or mulching 50,000 acres of forest and rangelands is more expensive than prescribed burning, due to increased labor and equipment needs. It would also decrease the number of ground cover plant species reducing food for wildlife. However, unlike prescribed burning, mulching does not produce any fire smoke.

Who would fund this program?

Montana is considering using some state revenue as matching funds to help federal, state, tribal and private individuals finance fire prevention programs. If a majority of residents vote to pay the county share of this program, the Mechanical Fire Fuels reduction Program would be implemented in your county and other counties in Montana on federal, state, tribal and private forest and rangelands.

Funding of the Mechanical Fire Fuels reduction Program would require that all users of Montana's forest and rangelands, such as timber companies, recreation visitors, and Montana households pay the additional cost of this program. If this Mechanical Fire Fuels reduction Program were to be implemented, by law, the money would be deposited in a separate Montana Mechanical Fire Fuels reduction Fund, which could only be used to carry out the Mechanical Fire Fuels reduction Program described above. A citizen advisory board would review the expenditures from the fund annually.

Results of the Program

If the Mechanical Fire Fuels reduction Program was undertaken instead of the Expanded Prescribed Burning Program, it is expected to reduce the number of acres of wildfires from the current average of approximately 140,000 acres each year to about 105,000 acres, for a 25% reduction. The number of houses destroyed by wildfires is expected to be reduced from 20 a year to about 8.

Your Chance to Vote

Your share of this Mechanical Fire Fuels reduction Program would cost your household $____________ a year. If the Mechanical Fire Fuels reduction program were the **ONLY** program on the next ballot would you vote?

1. In favor
2. Against

Demographics

These last few questions will help us understand how well our sample represents the State of Montana. Your answers are strictly confidential and will be used only for statistical purposes. You will not be identified in any way and your name or address will not be distributed or sold to any mailing list.

1) Have you ever been in or personally witnessed what you would consider a wildfire?

   a) Yes   b) No

2) Have you ever experienced smoke from a wildfire or prescribed burn?

   a) Yes   b) No

   If Yes did it bother you?

      a) Yes   b) No

   If Yes did it bother you?
      1. Visually
      2. Physically or
      3. Both

3) Do you suffer from respiratory or breathing problems?

   a) Yes   b) No

   If Yes, is it a…
      1. Serious
      2. Moderate, or
      3. Minor problem

4) Has your home ever burned or sustained structural damage from a wildfire?

   a) Yes   b) No

   Yes (# of times) ________________

5) Has one or more of your neighbors' homes ever burned due to wildfires?

   a) Yes   b) No

   Yes (# of times) ________________

6) Have you had to evacuate your home one or more times due to wildfire?

   a) Yes   b) No

   Yes (# of times) ________________

7) What county do you live in?

   (Name of County)______________________

8) How long have you lived in this county?

   ________________ # of years

9) What is your zip code here in Montana?

   ____

10) Was your zip the same in June 2000?

   a) Yes   b) No

   If No, what was your zip in June 2000?

   ____

11) Have you lived in other counties in Montana?

   a) Yes   b) No

   Yes, (list counties)_______________

   ____

   ____

12) How long have you lived in Montana?

   ________________ # years

Thank you for completing this survey. If you have any comments for us concerning this topic please feel free to express them with your interviewer