THE POLIITICAL ECONOMY OF PRESCRIBED FIRES:

A LAND AGENCY'S DECISION TO BURN

by

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TABLE OF CONTENTS

TABLE OF CONTENTS - CONTINUED

LIST OF TABLES

ABSTRACT

National land agencies ignite hundreds of prescribed fires every year throughout the Rocky Mountain West. When a national land agency proposes a prescribed fire they must by statute take public opinion into account before igniting the burn. The public interest of a prescribed fire may be to decrease the acreage of the burn in order to save animal habitat or possibly to stop a burn entirely. A theoretical model where a land agency maximizes a net social expected benefit was used to develop comparative static results in the empirical analysis. Using county Sierra Club membership as a proxy for protests, this thesis analyzes acreage differences and timing differences of prescribed fires. First, a probit model is used to evaluate the probability of a wildland urban interface prescribed fire. The regression results present a higher probability of wildland urban interface prescribed fires at the median of county Sierra Club membership as a percent of county population, *ceteris paribus*. County Sierra Club membership as a percent of county population was not statistically significant in explaining proportion acreage changes from proposed to actual acres burnt. Timing differences, on the other hand, were found to increase as county Sierra Club membership as a percent of county population increased, *ceteris paribus*. The empirical results imply that land agencies treat their prescribed fires that are in the wildland urban interface the same. There are also timing differences that can be explained through pressure from group interest in land agency policies.

CHAPTER 1

INTRODUCTION

National land agencies engage in controversial practices such as enhancing natural habitat through the use of prescribed fire. Through the use of prescribed fires, a land agency is able to clear debris on the ground in order to reduce the risk of a wildfire starting or spreading as rapidly as if it was not burned. Many people that live within the Wildland Urban Interface (WUI) have a strong interest in policy as do national groups that may be interested in the environment. Interest groups such as these have the ability to formally protest a fire for any aspect of a burn with which they do not agree. Using prescribed fires as an example, this thesis analyzes how a public land agency acts in the face of controversial policy issues.

The United States' federal government introduced the National Healthy Forests Restoration Act (NHFRA) in 2002 to implement explicit policies for a healthier forest system. NHFRA, which was enacted in 2003, included special emphasis on prescribed fires for fire prevention and general forest restoration. Because this enactment all national land agencies must burn a specified number of acres per fiscal year. Each district office within a land agency has the responsibility to enact and carry out their allotted amount of prescribed fire acres.

The National Environmental Policy Act of 1969 (NEPA), signed into law January 1, 1970, mandated the comprehensive analysis of environmental impacts of proposed federal projects (Williams, 2007). This means each national land agency must assess the environmental impact of all prescribed fires on land it plans to burn. Agencies are also required to consider public input for or against each prescribed fire. Public participation may lead to formal protest of a specific prescribed fire and more public interest in overall management of public lands. This not only holds true for individuals, but also environmental groups.

Previous prescribed fire research analyzes a land agency's decision to burn (Yoder 2005; Yoder 2003). There have also been papers on economic loss analysis of wildland fires and liability law for prescribed fires within the United States (Mercer 2007; Rideout 1995; Yoder 2003). While there has been significant research done on forest policy (O'Toole 1988) the NHFRA has not been evaluated. NHFRA also mandated electronic storage of data which allows an analysis of the policy.

The principal question this thesis addresses is: "are measures related to public input related to the agencies burn decisions?" More specifically, 1) do differences between planned and actual acres burned and 2) the planned and the actual dates of burns relate to measures of public interest? Put another way, when there is a group with strong interest in public land policy do they affect the timing of a prescribed fire? Prescribed fires are a complex issue between the national agencies, hunters, homeowners, and many other interest groups. A land agency's purpose, with respect to fire, is to enact prescribed fires to reduce ground fuels to prevent catastrophic wildfires. When an agency is trying to minimize economic loss resulting from a wildfire they are not likely to be minimizing an agency budget (O'Toole 1988), rather they are maximizing a social benefit further discussed in Chapter 3.

This research contributes to previous empirical research in political resource economics specifically pertaining to prescribed fires under NHFRA 2003.

This thesis is organized as follows. Chapter 2 discusses relevant theoretical and empirical literature. Chapter 3 discusses the applied theory of a federally run land agency. The theoretical model was developed in light of previous research and personal knowledge of a land agency managing forest lands. Chapter 4 discusses the variables and statistics used in the empirical analysis. Econometric results are presented in Chapter 5 and conclusions are discussed in Chapter 6.

CHAPTER 2

LITERATURE REVIEW

Prescribed Fire Literature

The literature on prescribed fire covers various topics of liability law (Yoder, *et al.*, 2003), the frequency of burning (Englin, *et al.*, 2000; Yoder 2004, 2007), and the effects thinning projects have on wildfire intensity (Pollet and Omi, 2002). Wildfires have far-reaching costs that can affect timber sales, houses and businesses. With more people living near the Wildland Urban Interface (WUI) prescribed fires have seen even more interest.

Mercer, *et al.* (2007) evaluate the economic viability of prescribed fires and their overall cost effectiveness. Mercer, *et al.*, use a dependent variable that should have a strong relationship to economic damages from a wildfire, the fireline intensity-weighted area burned divided by forest area. This intensity measure relates to how hot a fire burns rather than strictly the acreage it burns. This measure also allows Mercer, et al., evaluate the overall damage from intensity of the burn. Mercer, *et al.* (2007), find that using prescribed fires reduce both wildfire area and wildfire intensity. This result is consistent with prescribed fires reducing future risk in a manner that maximizes a net welfare criterion.

Mitchell, *et al.*, (2009) analyze prescribed fire escapes and liability law in the United States. When a prescribed fire is used and it escapes its bounds, it is then considered escaped, becomes a wildfire, and suppression efforts are used. According to current liability law the person, or group, that sets the prescribed fire that escapes is liable for any and all damage occurring from said fire (Mitchell, *et. al.*, 2009). Mitchell, *et al.*, use a count data model, specifically a hurdle model, to predict prescribed fire escapes. The data used consisted of a mail survey of 460 potential prescribed burners from Florida, Iowa, Minnesota, Missouri, Oklahoma, Oregon, Texas and Wisconsin. Florida and Texas conduct the most prescribed fires in the United States, while Midwestern states do fewer burns. Mitchell, *et al.*, find that conducting more burns leads to a more proficient crew and less likelihood of an escaped prescribed fire. Their findings also suggest that a group that mostly relies on prescribed burning for their income has a tendency to have fewer escaped prescribed fires than other groups that obtain smaller proportions of their income from prescribed fires.

Yoder, *et al*. (2003), consider economics and wildfire law. Yoder, *et al*. model prescribed fires through maximizing the total net value of a prescribed burn minus the expected value of damage and any costs of care incurred by the burner and victim. This model, as they explain it, is for private landowners who set prescribed fires on private property. Yoder, *et al*. (2003), main interest lies in a policy change in the Southeast that, they find, promotes more prescribed burning by private citizens. Liability laws vary from strict liability to negligence in the states they examine. States with strict liability hold the person that sets the burn liable for any and all damages incurred from an escaped prescribed fire. Other states now enact a negligence rule that states if a prescribed fire escapes and the neighboring area that receives damage from the fire has excessive fuel on its property the original burner is not liable for damage. This leads to legal incentives for all involved to increase the rotation of prescribed fires, or mechanical thinning, to reduce fuel loads. Although a free-rider problem would be expected when one person burns, it actually gives the neighbor the incentive to reduce fuels on their property, depending on the liability, so the fire does not escape into their land.

Previous fire literature looked at thinning and prescribed fire's effect on wildfire intensity. Pollet and Omi (2002) found that pre-suppression efforts such as thinning and prescribed fire reduced fireline intensity of a wildfire. Pollet and Omi's research used an ecological approach that involved observing various areas before and after a wildfire to visually assess thinning efforts by a land agency. Pollet and Omi also measured basal areas to compare stand densities before and after thinning efforts. While Pollet and Omi's approach to the model did not involve much data analysis, they did observe various visual aspects that supported pre-suppression support efforts such as visual recognition of reduced basal areas and decreased dead fuels. Mainly, Pollet and Omi found that the wildfires did not crown when there were pre-suppression efforts. Crowning is when a fire climbs ladder fuel from the ground to the tops of trees. This lack of crowning is mainly due to ground and ladder fuels reduction projects which include manual thinning and prescribed fire.

Because various papers can be found that have the same findings as Pollet and Omi (2002); Mercer, et al. (2007), conduct a study to see if prescribed fire reduces net economic damages from a wildfire. Mercer, *et al*., test a model developed to measure wildfire damage and risk. Their wildfire damage risk model uses a dependent variable of fireline intensity-weighted area burned/forest area. This variable is supposed to be more directly linked to economic damages from wildfire, a reasonable claim because fireline intensity is the amount of heat coming off the fire. Heat from fires can preheat fuels ahead of the fire thereby increasing the rate of spread. Using panel data from Florida from 1994 to 2001, Mercer, *et al.*, find that the amount of prescribed fire to minimize net damages depends on the chosen measure of damages from wildfire. The different measures evaluated are the dependent variable previously mentioned and also a simple percentage area burned of the total forest. Their findings for Florida are that increasing prescribed burning would be optimal to reduce damages.

Currently 38.6 million people live in and around the wildland urban interface (ISO, 1997). Having structures close to public lands increases the cost of fire-related losses with an average of 900 structures damaged each year (ISO, 1997). Lankoande, *et al*. (2009), use a model where property owners choose whether or not to move to fire prone areas, and if they do how much fire mitigation to choose. Lankoande, *et al*., approach this problem through an expected utility maximization problem of the individual who is considering moving where both decisions are made at once. Lankoande, *et al*., find that the price of standard insurance is too low for WUI residents and too high for urban residents. This is especially the case when new building takes place. Insurance premiums actually promote building in the WUI by offering a single premium where urban residents are overcharged and WUI residents are undercharged. Their solution is to offer mitigation-contingent insurance contracts to reach the optimal amount of private mitigation in the WUI.

In order to minimize costs of damage, prescribed burns should be optimally timed. Yoder (2004) and Reed (1984) have both done studies that support the burn often “mantra”. Yoder uses an optimal control function that depends on time, potential damage, a level of precautionary effort, the probability of damage, the value of production of the forested area, and the discount rate. His first finding is that timing and precaution are substitutes. This means that if an area is burned more often, less precaution can be used, but if it is burned less often then more precaution must be used. An interesting finding is when potential damage is high, then the intervals between burns should be shortened. Ironically this means that burning next to more expensive structures should happen more often. Next, Yoder finds that the liability rules matter. Given a liability rule requiring minimum precaution, there will be pareto optimal prescribed fire application, but not first-best. Finally, if prescribed fire is too risky, mechanical thinning may be an economically viable first-period supplement to reduce risk for further applications of prescribed fire. Too risky of a prescribed fire means there is a high probability of escape leading to a large expected cost of an escaped prescribed fire. Prescribed fires with a high risk value will, *ceteris paribus*, not be burnt because of a high expected cost of suppression efforts and property loss of structures and timber values.

Reed (1984) uses a stumpage value model, the difference of the costs of logging and delivery and the value of the cut timber. Reed’s findings are consistent with Yoder’s. First he finds that the presence of a fire risk would decrease the optimal logging rotation period. Therefore, when fire risk is high, there should be less time between rotations. Reed’s analysis is to maximize the timber value of an area, but his analysis has an overall emphasis on pre-treatment of forested areas. Therefore, whether it is prescribed fire or mechanical treatment, Yoder and Reed both find that the optimal timing should be less time between prescribed fires the higher the risk.

Economic Literature of Bureaucratic Agencies

Government agencies were initially modeled by most economists to be a cost minimizing agency that served the public. However there are other incentives that individuals within the government may seek to maximize. Niskanen (1971) was the first to formally present a bureaucracy as a budget maximizing agency. His rationale is that individuals within government maximize their utility. Through this utility maximization they may be trying to maximize their power, prestige, salary, reputation, or output. When an individual wants to maximize her utility in this setting she may seek to maximize the budget that she controls. “It is not necessary that a bureaucrat’s utility be strongly dependent on every one of the variables which increase with the budget, but only that it is positively and continuously associated with the level of the budget” (Niskanen, 1971, 38).

Many scholars, e.g., Johnson and Libecap (1994) and Wilson (1989) have challenged the budget maximization assertion. Johnson and Libecap do not find a strong correlation between federal bureaucrats’ salaries and the size of the agency. Wilson, on the other hand, stresses that the autonomy of an organization is essential. He emphasizes that there is a trade-off between larger budgets and agency autonomy.

Niskanen (1971) contends that a bureau receives its funding from a sponsor (legislative or executive branch of the government). The bureau is able to estimate the sponsor's willingness to pay while the government sponsor has a hard time estimating the minimum budget that would maintain that bureau's productivity. A government agency has many roles to fill and is unlikely to take the necessary time to figure out the bureau's costs. Also, a government agency does not have the necessary resources to offer the bureau the minimum pay to keep productivity at the same level. Niskanen (1971) holds that the bureau tries to maximize the budget because they are the only agency offering a specific service. Although Niskanen's model has been challenged, he is confident enough to offer "those bureaucrats who doubt this proposition and who have good private employment alternatives should test it… once" (Niskanen, 1971, 38). While this statement is clearly debatable, it offers the implication that many government bureaus may in fact seek budget maximization, if not merely a stable budget, and that cost cutting within the government is a negative outcome for the individual in charge. Cost cutting in the private industry is often encouraged and rewarded, but there are not proper incentives in place to make a government agency seek out proper budget cutting.

To summarize, prescribed fire research covers many topics but those that are most pertinent to this paper involve liability law and the frequency and timing of burns. Yoder (2003, 2004) presents multiple papers analyzing private liability law in the United States and evidence for higher frequency of prescribed fires. Reed (1984) also offers evidence for a higher frequency of prescribed fires. Also, Mercer, *et al.* (2007), analyzes the validity of prescribed fires for the reduction of net loss from wildfires and finds that burning more frequently would reduce net loss of economic damages to timber and structures. In each of these papers presented, there is a common theme that an agency should burn more frequently than they currently are burning. If an agency wants to reach the optimum prescribed fire usage, changes may need to be made to political aspects of prescribed fire so delays occur less frequently.

Niskanen (1971) argues that bureaucratic agencies may seek to maximize their budget for personal and professional gain. Johnson and Libecap (1994) and Wilson (1989) argue that there is not a strong correlation between an agencies budget maximization contention and the size of an agency. Johnson and Libecap (1994) state that the autonomy of an agency is more critical an issue to budget allocation than personal and professional gain of the individual within the agency. Given these arguments, I approach this thesis with a theoretical model that seeks to maximize a social benefit subject to a budget constraint.

CHAPTER 3

THEORY

I consider a public land agency, such as the United States Forest Service or Bureau of Land Management, as an agency that maximizes an expected net social benefit. The model analyzes two unique agency outcomes of 1) a controlled burn, which implies a low expected cost of a wildfire, or 2) no controlled burn, which would imply a higher expected cost of a wildfire. While there are other actions of these public land agencies such as trail maintenance, recreation, water concerns, and archeology, this thesis only analyzes the agency's decision to carry out a prescribed fire with a focus on political issues such as formal protests. With an at times controversial issue such as prescribed fires I am able to analyze a public land agency's decision in the face of adversity. The agency's decision variables include the size of the fire, its timing, whether or not the burn is in the Wildland Urban Interface (WUI), and other political issues related to the burn such as wildlife habitat protection and various visual and aesthetic issues.

The first agency decision would be whether the land agency completes all of the desired or planned burns for a given fiscal year. If the agency's budget was large enough the agency could carry out all of the desired burns. If the agency does not spend its entire budget in one year, the budget might decrease the next year. The land agency may have a lot of burns one year, and therefore a larger budget the next year, and then have fewer burns the next year, thereby not using the entire budget. Also, the proper incentives are unlikely to be in place where agency personnel have a stake in the optimization. An example of an incentive is where the employee received pay based on total benefit, but such mechanisms are likely too unwieldy in an agency setting and are rarely seen.

The first-best decision, which is the optimal burning rotation of a piece of land, is likely unobtainable. The optimal timing of a burn varies depending on stand density, distance to the WUI, and various other fuel measures. First, because agency land managers do not receive any rents directly related to the benefit of the prescribed fire, they may have imperfect incentives to maximize the objective equation. Second, politicians and interest groups may seek to influence agency output, taking the agency's decision away from a social optimum. This happens when a group or person can, for instance, write the land agency formally protesting a specific prescribed fire. Third, people within the agency may have different ideas as to the optimal prescription. This discrepancy could result from the main prescription writer only looking at past pictures of the land rather than the burn boss who is in the field observing the landscape. Therefore, one of the persons may actually have better knowledge of the optimal prescription than the other. Fourth, land agencies must adhere to certain rules and regulations that can delay or stop a prescribed fire.

The second-best solution is reached by the agency due to these constraints. When an agency has improper incentives or other constraints in decision making, the sub-optimal solution will be chosen. Therefore, the optimal decision may be to burn, but because of time and budget constraints, the agency may not burn. Alternatively, there are also other characteristics of the burn that differ from the optimal. If a burn site has been chosen, but an interest group formally protests, then the optimal timing may be altered because of the potential for further litigation or prescription changes. That is, the optimal burn still occurs, even if its timing is not optimal. This effect may be in part due to the National Healthy Forests Restoration Act of 2003. Before 2003 a prescribed fire may have been completely cancelled, but due to NHFRA land agencies have to burn a certain amount of acres each fiscal year.

The public land agency is taken to maximize the social benefit (B(x,y)) given by:

(1) Max Expected Benefit = $P_{wi}^{NCB}C_{wi}^{NCB}-P_{wi}^{CB}C_{wi}^{CB}+E_i$

(2) s.t. $M=\sum p_i x_i$

The social benefit in equation (1) depends on various costs and probabilities. First, there is an expected cost of a wildfire given no controlled burn. The expected cost is defined by its probability and cost as $P_{wi}^{NCB}C_{wi}^{NCB}$, respectively. Second, there is the expected cost of a wildfire given a controlled burn. This expected cost is defined by its probability and cost as $P_{wi}^{CB}C_{wi}^{CB}$, respectively. Third, when a prescribed fire is carried out there is an external benefit, E_i, that areas directly next to the burn site receive.

The various variables within equation (1) are all dependent upon an **x** vector and a **y** vector. The **x** vector contains the agency choice variables and the **y** vector contains the exogenous parameters. The **x** vector includes the size of the burn, prescription type, equipment such as engines, hoses, hose fittings, drip torches and hand tools, and personnel. The **y** vector contains various parameters that include rainfall, temperature, relative humidity, and type of fuel (grass, pine trees, etc.). These variables are omitted from equation (1) due to readability.

The probability of a wildfire without a previous controlled burn is expected to be higher than if there was a controlled burn there. The cost of a wildfire would also be larger when there was no previously controlled burn because there would be more fuel on the ground to increase the temperature of the fire thereby heating other fuel faster and moving faster. Also, when more fuel is on the ground, the increased heat keeps firefighters back farther from the fire which increases the fire size, *ceteris paribus*. On the other hand, the probability of a wildfire should be relatively small when a controlled burn was previously enacted because it reduces the fuel load in the undergrowth of the forest. This means there is less fuel for lightning or a person to ignite thereby decreasing the probability of a wildfire. Because there is less fuel, even if a wildfire starts, it will cost less because it will not burn as hot, allowing firefighters to get closer to the fire and stop it faster.

When an area is burned previously and a wildfire starts, firefighters can more effectively fight the fire on the ground rather than having the fire crown. When a fire crowns it means that the fire has gone up the ladder fuel and is burning in the tops of trees. If the fuel on the ground can be kept to a minimum, then the heat is unlikely to ignite the tops of trees, thereby making the fire easier to fight. The differences among these expected costs relate primarily to vast acreage differences between large and small wildfires along with personnel and equipment differences in order to contain the wildfire. When the fire is on the ground, more firefighters can be used, along with engines, to fight the fire. On the other hand, if the fire crowns, then helicopters and bulldozers will most likely need to be employed in order to fight the fire. Although manual labor may seem to have higher costs, hiring helicopters and pilots will be much more expensive because of specialized labor.

The difference between these two expected costs in equation (1) is combined with an external net benefit ($E_i(x,y)$) that comes from a prescribed burn. An area directly next to a burn site might see increased activity from hikers or wildlife because of the decreased fuel load. When an area is burned properly, there is less fuel on the ground to reach various goals such as habitat restoration for wildlife, restoration for recreation, removal of invasive species, etc. Although an area may have a different prescription, there may be external benefits for areas directly next to the burn site. For example, an area may be burned for sight, but this burn may increase animal activity because brush has been removed. Prescribed fires have various prescription goals such as sight, animal habitat restoration, recreation, etc. When a burn is classified for sight it is in a highly trafficked area next to a major road and agencies try to keep the burn low to the ground and out of the tops of trees. The actual prescriptions of all prescribed fires are allowed a certain amount of trees to be burned per acre but sight effects are to be kept to a minimum. Also, it is beneficial to keep a prescribed fire from burning too hot because then it can scorch the area rather than burning just the excess fuels. At the actual burn site this means minimal crowning to allow for an unburned look in the tops of trees. There are, on the other hand, some negative effects of the burn that include view shed destruction, damage to animal dens, etc.

Other prescriptions seek to clear an area of invasive species. Invasive species are classified differently in different areas. In some areas agencies like to have more hardwoods and will therefore burn more pine, or vice versa. Other times, invasive species can mean a non-native weed. A prescription to promote hardwoods will allow the burn to clear an area, say a watershed, of pine trees to allow for more hardwoods. A wildfire would most likely burn all the hardwoods along with the pine trees and would potentially decrease hardwood habitat. If a lightning strike were to hit in the area after a prescribed fire, there would be a lower probability of a wildfire starting and spreading to other areas. Therefore, we should see benefits to the area and also adjacent areas should also see external benefits because there is a decreased fuel load thereby decreasing the probability of a wildfire starting or spreading as fast.

Historical data show the probability of a controlled burn escaping to be very small. However, even if the probability of the burn escaping is very small, there could still be large expected costs associated with the controlled burn, especially in WUI cases. If there was a small WUI prescribed fire and it was next to expensive houses, the expected costs might be high. Critical to this issue is that certain areas will have good natural barriers, such as rivers or rock outcroppings, while others will not. For instance, if an area is identified to burn but is on a steep slope, the agency will most likely decide not to burn. On a steep slope rising heat preheats the fuel upslope which can cause a controlled burn to escape and become a wildfire. Such an escaped prescribed fire can have large containment costs.

The benefit that is being maximized, equation (1), is subjected to an agency fire budget, equation (2), ($M=\sum x_i p_i$). This is assumed to be binding. The budget constraint contains the $\underline{\mathbf{x}}$ vector previously introduced and the price ($\underline{\mathbf{p}}$) of those variables. M contains the budget allocation of the agency. Some of these prices are direct as per the equipment that includes hose, hand tools, drip torches, and hose fittings. The more indirect costs are the personnel wages that make decisions towards the size of the burn and the prescription type.

The benefit being maximized, in equation (1), is an increasing function. The point where the marginal benefit is equal to the marginal cost is the optimal net social benefit, given the parameters. The envelope theorem is used for simplicity to derive comparative static results.

Using the first order conditions (FOC) and assuming the implicit function theorem holds the envelope theorem gives:

$$\underline{x}^*(y,p) \text{ and } \lambda^*(y,p).$$

$\underline{x}^*(y,p)$ and $\lambda^*(y,p)$ represent the optimal x and λ given the parameters. They hold for all values of y and p.

(3) $\Phi(y,p)=B(\underline{x}^*(y,p),y)$ by FOC's
$\partial x/\partial y?0$

There are no comparative static results at this level of generality because the $\underline{\mathbf{y}}$ terms enter every first order condition. A linearity assumption was used for the cost functions, but this did not allow any comparative static results.

Because this model does not yield any comparative static results, I will discuss the theory behind what would be expected. Equation (3) is very general but can be talked about in detail to get theoretical predictions for the comparative static results.

Consider the comparative static $\partial x/\partial y$ where x is proportion acre change and y is lagged precipitation. Lagged precipitation affects the fuel load of the area. When more precipitation falls, there will be more shrubs, grass and trees that grow in the future. This increased fuel load should increase the optimal x, which is proportion change meaning a smaller actual burn, because there is more fuel and the prescribed fires would burn hotter. On the other hand, current precipitation, another exogenous y variable, would allow a larger burn, a decreased x, because the fuel is not as dry. With a higher relative humidity of the air and the fuel, the fire will burn slower and less intensely. This means less probability of escape for a given area. Therefore, more acres will be chosen, meaning less of a proportion change in x, because there is a lower risk of escape. Because an agency goes through a long process of approving a prescribed fire, choosing more acres at the last minute is not generally an option. An agency will choose to do a larger acreage burn rather than a smaller acreage burn during a month with above average precipitation for the area or they will burn their proposed acreage, if it is a smaller burn, as opposed to burning less than the proposed acreage. Such months will most likely be in the winter when snow is still on the ground to facilitate low probability of escape.

To further relate to the acreage changes of a prescribed fire, consider $\partial x/\partial y$ where x is the proportion acreage change and y is the number of people protesting. When a person or group, such as the Sierra Club, protests they have multiple reasons for doing so. One possible reason for protest is animal habitat protection. In this scenario, if a species of interest is within the burn site the protesting group may want that area excluded and therefore decrease the burn area. This would cause x, the proportion acreage difference, to increase.

The timing of a burn is critical for a prescribed fire. Consider $\partial x/\partial y$ where x is month's difference between planned and actual burn dates and y is protests. Again, when a person or agency protests they have multiple reasons for doing so. An agency must respond to these protests by explaining why the burn has a certain prescription or acreage size. In doing so, the agency takes additional time to analyze the prescribed fire. This would cause a delay in the actual burn date.

Another comparative static example is the comparative static $\partial x/\partial y$, where y is the number of people that protest and x is personnel. When more people protest the agency may choose to have more personnel (x) on the burn. If a prescribed fire is being protested, the public may be concerned for public safety whether it is smoke, a health issue, high risk of escape, or possibly they are concerned about the view shed. In any case, the agency will choose more personnel either to reduce risk of escape or simply to better carry out the prescription of the burn, in the eyes of the public.

Neither of these scenarios results in a definitive prediction. Rather, this discussion provides some intuition for the potential sign effects of these variables.

Another approach to derive comparative static results with respect to prices is with a cost minimization model.

(4) $L=BA(x_i,p_i)+\mu B(x_i,y_i)$

This cost minimization problem does not allow for comparative static predictions because it is also too general an equation to get specific predictions. Equation (4) is a cost minimizing Lagrangian equation where the budget allocation ($BA(x_i,p_i)$) is minimized subject to the net expected benefit ($B(x_i,y_i)$). Although this model is not used specifically for comparative static results, the theory will be talked about below.

Consider $x^*(y_i,p_i)$ as acres burned. When an agency carries out a prescribed fire they are dependent upon various prices of firefighters, hose, chainsaws, drip torches, etc. Also, an agency is dependent upon various environmental factors such as current precipitation, fuel load, slope steepness, etc. Because an agency receives pre-approval years in advance for a prescribed fire, price changes to firefighters may drastically change acreages actually burnt. This means fewer firefighters are able to monitor the prescribed fire and the risk of escape increases. Fewer acres will be burnt with an increase in price to firefighters. Group interest in public land agency policy can change the optimal acres burnt through formal protests to an agency. If a group, for example, wanted to protect animal habitat the actual acreage burnt may decrease in response to public protest.

Consider $x^*(y_i,p_i)$ as the timing of a burn. As is stated above an agency is dependent upon various prices and environmental factors. An agency is mainly interested in environmental factors when choosing the optimal planned burn date. Agencies need to choose an optimal time to burn when a particular area has a lower fuel load in order to decrease the risk of escape. Optimal timing of the burn is also important when considering current precipitation because an agency wants higher precipitation when they burn to decrease the risk of escape. Agencies must adhere to rules that require various weather factors to be within a set range, so the burn may be delayed because of various weather factors. Lastly, group interest in public land policy can extend the timing of a burn from its optimal timing through formal protests to an agency.

CHAPTER 4

DATA

Variables and Data Collection

This chapter introduces the relevant variables and data used for an empirical test of the model presented in Chapter 3. The data were gathered at the county level for the Rocky Mountain West states of Colorado, Idaho, Montana, Utah, and Wyoming.

The data were compiled from various sources including: The National Fire Plan Operations and Reporting System (NFPORS) that holds data from the United States Forest Service (USFS), the Bureau of Land Management (BLM), the National Parks Service (NPS), the Fish and Wildlife Service (FWS), and the Bureau of Indian Affairs (BIA); the Census Bureau; the National Oceanic and Atmospheric Administration (NOAA); and the Sierra Club.

The most recent electronically available data are from 2003-2005. This period provides more than 2,000 observations for the five states through three years. The data are available because of the National Healthy Forests Restoration Act of 2003 (NHFRA). Because this was signed into law the agencies must provide the data electronically rather than in paper form.

Across all national agencies there are 2147 observations, with 157 for the BIA, 385 for the BLM, 66 for the FWS, 87 for the NPS, and 1,452 for the USFS (Table 1). Wildland urban interface (WUI) prescribed fires consist of over half of the prescribed fires. The WUI is an area of federal land that is directly next to a structure of some sort.

The structures can consist of barns, houses, or garages. As more people move into the countryside, the WUI becomes more prevalent with structures requiring more protection from wildfires.

Table 1. Prescribed Fires by Agency.

Agency Name	Number of Prescribed Fires	Percent of Total
BIA	157	7.3
BLM	385	17.9
FWS	66	3.1
NPS	87	4.0
USFS	1,452	67.6
Total	2,147	100.0

Prescribed fires in the WUI are unevenly spread between the agencies, with the USFS implementing the most WUI prescribed fires with 977 (Table 2). The FWS implemented the fewest WUI prescribed fires with twelve (Table 2). WUI acres are shown by agency in Table 3. The NPS and USFS burn the most in the WUI with each agency having nearly 50 percent of its acres being burned in the WUI. Table 4 shows the total acreage each land agency manages within the five states. The USFS and the BLM have the most land and are also doing the most WUI prescribed fires. By acreage, though, the BLM is only is burning 26 percent of its total acres in the WUI. The BLM manages more land than the USFS (Table 4) but the USFS implements more prescribed fires, by acres and number of burns, and more WUI prescribed fires, also by acres and number of burns. This discrepancy can easily be explained through general land features of each agency. The USFS manages more forested areas that can be extremely thick with tall trees. The BLM, on the other hand, manages lower elevation and lower rainfall lands.

Therefore the BLM is able to use more wildand use fires rather than prescribed fires. In wildland use fires the land agency lets a naturally occurring fire burn naturally until it burns itself out.

Table 2. WUI Prescribed Fires by Agency.

Agency	Number WUI Prescribed Fires	Percent of Total	Percent of Total by Agency
BIA	84	6.3	53.5
BLM	194	14.6	50.4
FWS	12	1.0	18.2
NPS	59	4.4	67.8
USFS	977	73.7	67.3
Total	1,326	100.0	N/A

Table 3. Percent WUI Acreage.

	WUI Acres	Total Acres	WUI Percent
BIA	11,443	36,786	31%
BLM	55,741	215,242	26%
FWS	3,374	17,199	20%
NPS	7,420	14,266	52%
USFS	171,641	360,935	48%

Table 4.Total Acreage by Agency.

Land Agency	5 State Acreage Controlled by Agency	Percent of Land
BIA	8,316	4.8
BLM	69,499	40.4
FWS	18,552	10.8
NPS	6,333	3.7
USFS	69,277	40.3
Total Acreage	171,977	100.0

Dependent Variables

Actual Acres – Planned Acres: This variable is used to analyze agency changes on optimal burning size. Planned acres are measured by the individual writing the prescription using a Global Positioning System (GPS) when the proposal for the burn is written. Actual acres are also measured with a GPS after the burn is completed. Some slight measurement error is expected in the data because not all fires end on an exact acre, due to human error, and because GPS systems also have measurement error of .3 meters (Parkinson 1996). The signed difference between the two acreage measures is predicted to be small in absolute value when few to no people formally protest the fire and large when many people protest. These theoretical predictions were discussed in Chapter 3 where this variable would be expected to be negative if there are protests. The range for this variable is very large (Table 5). The negative mean is showing that on average the planned burn is larger than the actual burn. Because of the nature of the explanatory variable the relative acre difference of this next variable will be considered.

[(Actual Acres – Planned Acres)/Planned Acres]: This ratio is used to normalize the data. This proportionate difference allows comparison of differences more even-handedly, as a proportion of acreage differences from what the agency planned to burn compared to what was actually burned. There are large enough acreage differences in the data set, with, for example, one prescribed fire that has a thousand acre difference which is only 20 percent of the planned acres and another smaller fire that has 5 acres of difference which is also 20 percent of the planned acres.

Table 5. Variable Summary.

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
WUI	2147	0.6176	0.4861	0	1
Actual - Planned Acres	2147	-10.3135	380.5595	-7800	9730
Proportion Acre Difference	1939	-0.0150	0.7755	-0.9925	19
Actual - Planned Completion (Months)	2147	-0.5649	5.6972	-48	67
County Median Income	2147	26449.97	9156.06	14292	89028
County Population Density	2147	20.2592	66.6394	0.3	896.6
County Sierra Club Membership	2147	103.4793	432.1705	0	4938
County Sierra Club Membership Density	2147	0.0012	0.0039	0	0.0222
5 Month Mean Lagged Precipitation	2147	0.9918	0.2519	0.4364	2.5225
Current Month Mean Precipitation	2147	1.0207	0.5795	0.0087	4.9662
BIA	2147	0.07313	0.2604	0	1
BLM	2147	0.1793	0.3837	0	1
FWS	2147	0.0307	0.1726	0	1
NPS	2147	0.0405	0.1972	0	1
USFS	2147	0.6762	0.4679	0	1
WUI	2147	0.6176	0.4861	0	1
CO	2147	0.2077	0.4058	0	1
ID	2147	0.2342	0.4236	0	1
MT	2147	0.3521	0.4778	0	1
UT	2147	0.0922	0.2894	0	1
WY	2147	0.1136	0.3175	0	1
Planned Initiation Year	2147	2004.13	0.8285	1999	2009
Planned Initiation Month	2147	8.1882	2.9539	1	12
Planned Completion Year	2147	2004.13	0.8285	1999	2009
Planned Completion Month	2147	8.3097	2.0971	1	12
Actual Initiation Year	2147	2004.15	0.7683	2003	2005
Actual Initiation Month	2147	7.0239	3.2641	1	12
Actual Completion Year	2147	2004.19	0.7778	2003	2006
Actual Completion Month	2147	7.0237	3.1122	1	12
Planned Acres of Burn	2147	310.4662	812.4904	0	15637
Actual Acres of Burn	2147	300.1528	823.0458	1	15637

Actual Burn Month – Planned Burn Month: Optimal timing of a burn, discussed in Chapter 2, is hard for the agency to attain because of environmental paperwork and formal protests. Given that previous research shows agencies are not burning at optimal times, this timing difference is used to evaluate agency efficiency plus the effects of protest as a whole. This variable measures the difference between the actual and planned burn months. If these dates are within a few months of each other weather and other factors may be playing a major role rather than protests. Alternatively, if the difference is large, formal protests may be causing long delays, or the agency is less efficient than others, or both. The actual month and year the prescribed fire was carried out is dependent upon many factors that mainly consist of various local weather factors where the burn is taking place. If the burn is uncontested, then this time difference between actual and planned burned month should be zero or close to zero, *ceteris paribus*. There are expected to be differences in this variable because of weather that are controlled for using independent weather variables. The planned burn month is stated in the proposed burn plan. The agency will set a proposed burn month and year that is either the start of their fiscal year or an actual month they will most likely have the best weather. There is a large variability in this variable (Table 4). This variable is measured in months and as an example a fire planned to burn in October 2005 but actually burned in October 2006 has a value of 12 months. The largest time period difference of planned completion to actual completion shows a difference of 67 months (Table 5). Although some districts will put in the start of their fiscal year (October) as planned burn date, it is still within an optimal time period to burn. We can expect some differences from agency to agency, but this is controlled for through agency dummies.

Independent Variables

The independent variables (Table 5) consist of control variables for weather, and state dummies, agency dummies, a wildland urban interface dummy, and county-level demographic data.

Median Income: The median income of a county is thought to be related to two important factors that are not readily available for a sample. The first factor is the educational level within the county. The more educated a person is the higher income that person will make, *ceteris paribus*. The second factor related to this variable is controlling for house prices, with higher income counties expected to have a higher median house value. This is especially important for WUI prescribed fires because a land agency is liable for damages from escaped burns.

Population Density: Population density is used rather than population because county sizes differ considerably in the sample. This population density measure of population per square mile provides a comparable measure across counties.

State Dummies: Differences between state laws and general social-economic population differences are controlled for through dummy variables. Differences in controlled burns among states could be from factors as small as procedural differences of an agency or could be from factors as large as political influences of policy of an area.

For example, political influence could encourage an agency to have a controlled burn next to wildland urban interface to save structures should a wildfire start. State social norms can also be different regarding forest policy and enactment.

Agency Dummies: There are various changes a federal agency can make to their local agency policies from state to state. Influences for these differences could come from public pressure or from the head of an agency. All agencies being analyzed in this thesis are federal and have federal oversight. Although all districts within the various agencies are run separately, using dummies for each district is infeasible in this data set.

Current Precipitation: The current median precipitation of a month normalized to a 60 year mean will control for timing and acreage differences in the month of the prescribed fire that are due to too much or too little precipitation. With too much precipitation a prescribed fire could be put on hold because the fuel load will be too wet to ignite. On the other hand the precipitation could be too low and policy mandates the fuel cannot be burnt because it does not meet a set relative humidity percentage, denoting the fire will burn too hot and have a high potential to get out of control. The variable is explicitly defined as total monthly precipitation divided by a 60 year total monthly average.

5 Month Aggregate Lagged Precipitation: The amount of past precipitation an area receives indicates how much fuel on the ground is available to burn. Trees, shrubs, and other plants will grow more during a month when there is increased precipitation. With an increased fuel load an agency will wait to do the burn because of a higher

probability of escape. With below average precipitation an agency would have less fuel on the ground. When little variation is seen within the actual-planned burn month it may be due to this variable. Therefore, precipitation and more importantly, lagged precipitation, is important to control for within the burning decision for an agency. Explicitly, this variable contains the summation of five months of rainfall divided by the 60 year total average for the same time period.

Wildland Urban Interface: The wildland urban interface is the area directly next to a structure and is a dummy variable. The structure is defined to be any sort of structure, inhabited or uninhabited. Structures can mean anything from a commercial building to a barn to a house. Extra precautions must be taken when burning next to these areas because if a burn should escape the land agency is liable for damages to man-made structures. Therefore, most burns done next to structures are an acre or less.

County Sierra Club Membership: This variable is used as a proxy for formal protests of a prescribed fire. A Sierra Club member is self selected to have interest in the outdoors and public land management. For this reason this is a useful variable for political interest in a public land agency. Formal protests, which this variable proxies for, should have a negative effect on the timing of prescribed fires.

County Sierra Club Membership/County Population: Membership varies between counties and this variable is a percent of county population to normalize the data for population differences.

Table 5 shows a summary table of the data being used in the analysis. Prescribed fires vary widely in size and scope, with many different prescriptions put into effect for various areas. Prescribed fires in the WUI and around recreation areas are expected to have the most interest from the public and are therefore expected to be protested more often than burns farther into a forested area. Table 11 also shows the correlation among variables of interest.

Prescribed Fire Data Collection

The prescribed fire data were gathered from the National Fire Plan Operations and Reporting System (NFPORS). All of the national land agencies, the Bureau of Indian Affairs, the Bureau of Land Management, the Fish and Wildlife Service, the National Park Service, and the United States Forest Service, report their yearly data to the NFPORS.

All available dates for the proposed burn dates and the actual burn dates are collected through the NFPORS. A land agency writes an initial proposal for a prescribed fire with all the necessary agency documents and NEPA analyses of the burn site. When the burn plan is approved by the national and local field offices, the local office announces the prescribed fire for public opinion. At this point, the project has a time period for formal protests in which persons or groups write in airing their grievances regarding the proposed burn. The land agency must then respond to the objections through various channels. These responses can involve canceling the burn, changing the acre size, changing the actual prescription goals, or changing the prescription itself. Once changes are made and the project is approved, the land agency then carries out the planning process in the proposal. If a burn is cancelled due to protests they are not included in this data set.

The land agencies use wildland firefighters to physically collect the raw data at the actual site of the prescribed fire. Firefighters use handheld GPS units to walk around the perimeter of the proposed prescribed fire to calculate the proposed acreage of the burn. The acreage is also collected after the burn has concluded to record the actual perimeter of the prescribed fire. This data are the proposed and actual acres for a prescribed fire.

CHAPTER 5

EMPIRICAL RESULTS

This chapter report and discuss the results of empirical tests of the hypotheses discussed in Chapter 3 in this chapter. The key hypothesis being tested is whether acre differences or timing differences occur when people or groups have a strong interest in public lands policy; this chapter also evaluates state and agency differences in acreage burned and the timing of the prescribed fire.

The empirical analysis uses regressions of the controlled burn data described in Chapter 4. The sample size is 2,147 prescribed fires from the five states of Colorado, Idaho, Montana, Utah, and Wyoming. The data also covers the federally run land agencies of the Bureau of Indian Affairs (BIA), Bureau of Land Management (BLM), the Fish and Wildlife Service (FWS), the National Park Service (NPS), and the United States Forest Service (USFS). The empirical model was estimated using an initial probit model to evaluate the probability of a Wildland Urban Interface (WUI) prescribed fire and Ordinary Least Squares (OLS) for both timing differences and acreage differences of the prescribed fire.

Total county Sierra Club membership is a proxy for interest in a land agency's policies. In the regression results presented throughout this chapter Sierra Club membership is normalized as a percent of county population. Tables 12, 13, and 14 present the same regressions but with total county Sierra Club membership instead of

Sierra Club membership as a percent of county population. The results show the Sierra Club variable is statistically insignificant.

Regressions and Results

Probit Model for Wildland Urban Interface Prescribed Fires

The probit regressions (Table 6) analyze the probability of a WUI prescribed fire controlling for planned acres, income level, population density, county Sierra Club membership relative to county population, average monthly precipitation, agencies, and states. The purpose of this regression analysis is to analyze the frequency at which an agency is choosing to burn in the WUI and how these fires relate to demographic and other key variables. These results provide insight into the agency decisions across states.

The first two probit regressions (Table 6) show the probability of a WUI prescribed fire. Planned acres are omitted in regression 1 because of a possible simultaneity bias in the agency decision. When an agency decides to do a burn, they most likely decide on acreage and type of burn at the same time. This means that the classification of WUI and planned acres may be decided simultaneously. Planned acres are omitted from the first regression in order to compare the variables from the two regressions. As is seen in Table 6, the coefficients and test statistics are relatively stable. The results from regression 2 are discussed below.

Table 6. Probit Regressions for WUI Fires.

WUI	Regression 1	Regression 2
Planned Acres		-0.0003***
		(-7.09)
Median Income	1.22e-06	9.17e-07
	(0.26)	(0.20)
Population Density	0.0040***	0.0039***
	(4.90)	(4.89)
County Sierra Club Membership/County Population	20.2011**	16.8358*
	(2.10)	(1.75)
Current Precipitation	-0.0411	-0.0451
	(-0.83)	(-0.91)
5 Month Lagged Precipitation	0.1017	0.1085
	(0.90)	(0.95)
BIA	0.0553	-0.0032
	(0.44)	(-0.03)
FWS	-1.3568***	-1.4166***
	(-6.11)	(-6.38)
NPS	0.3262**	0.2555
	(1.96)	(1.52)
USFS	0.3906***	0.3492***
	(5.08)	(4.48)
Colorado	0.2873**	0.2444**
	(2.53)	(2.13)
Idaho	0.3365***	0.3222***
	(2.86)	(2.70)
Montana	0.2016*	0.1386
	(1.79)	(1.22)
Utah	0.1068	0.1077
	(0.75)	(0.75)
Constant	-0.3367	-0.1648
	(-1.55)	(-0.75)
Pseudo R^2	0.0576	0.0773

2147 Observations
(t-stats in paranthesis)
two-tailed t-stats
* 10% statistical significance
** 5% statistical significance
*** 1% statistical significance

The planned acres of the prescribed fireis statistically significant at the 1 percent level and has a negative estimated coefficient. The idea that a prescribed fire next to the WUI is smaller in acreage is supported by this coefficient. The coefficient value for this variable at the mean gives an estimated 9.3 percent decreased probability of a WUI prescribed fire with mean planned acres of 310.46.

Median county income, the variable controlling for house values in this regression, is statistically insignificant. This variable is expected to be positive because a land agency tends to burn more next to structures with a higher value (Yoder 2004).

County population density is statistically significant at the 1 percent level. As the population density of a county increases the land agency is more likely to burn next to a structure. Sierra Club membership of a county is positive and statistically significant at the 10 percent level. At the mean value of county Sierra Club membership per population (Table 4) the probability of a WUI prescribed fire increases 2.0 percent, ceteris paribus.

The current and 5 month lagged average monthly rainfall adjusted for a sixty year average is not statistically significant when explaining WUI burns. Note that when fires are planned next to the WUI the fire crew usually prepares the site extensively by cutting down ladder fuels and possibly making piles of dead brush. Because this precipitation variable is controlling for fuels and the land agency will sometimes pre-treat the area, it is not surprising that this variable is insignificant in this regression.

The base agency in this regression is the Bureau of Land Management (BLM). Agency dummies are statistically significant as a group at the 1 percent level with an F-test value of 68.10. Specifically the USFS, which is statistically significant at the 1 percent level, is almost 35 percent more likely at the median to burn in the WUI than the BLM while the FWS is statistically less likely to have WUI prescribed fires. This is likely explained by the type of lands each national agency manages. The USFS has a great deal of land next to the WUI (Chapter 3) whereas the FWS has very little land next to the WUI (Chapter 3).

The state fixed effects are statistically significant as a group at the 10 percent level with an F-test of 7.06. Colorado is statistically significant at the 5 percent level and Idaho is statistically significant at the 1 percent level. At the mean Idaho is 33 percent more likely to burn in the WUI than Wyoming. Colorado, on the other hand, is 23 percent more likely to burn in the WUI, at the mean, than Wyoming.

Overall, this regression analysis provides some information regarding where an agency is burning. Statistically, there are differences between agencies and states when burning in the WUI. Agencies that burn more acres in the WUI (Chapter 4), such as the NPS and the USFS, have an increased probability of burning in the WUI than the BLM. Also, state fixed effects were shown to be statistically significant, with Colorado, Idaho, Montana, and Utah have an increased probability for burning in the WUI relative to Wyoming.

Ordinary Least Squares of Timing Differences

This section analyzes timing differences from the actual to the planned date, in months, of the burn. This difference provides us with one way to evaluate how interest group pressure of burns and agency efficiency influence controlled burns. As was shown in the probit model, there does not appear to be simultaneity bias related to WUI prescribed fires. Results from a robust estimation that corrects for heteroskedasticity, regression 4, are the focus below.

Timing differences of the prescribed fires are evaluated in Table 7. When a person or group has an interest in a prescribed fire there may be timing differences from when the prescribed fire was planned to be initiated and when the actual prescribed fire was set. These timing differences happen because once a prescribed fire is protested the land agency will reevaluate the objectives of the burn plan. The dependent variable, actual burn date – planned burn date, is measured in months.

The regressions in Table 7 show ordinary least squares results (regression 3) and the robust regression results (regression 4) for the dependent variable of the difference, in months, between the planned and actual start date of the prescribed fire. This regression analysis shows us timing differences, in months, of burns when controlling for the WUI, median county income, county population density, the percent portion of county Sierra Club membership, monthly average precipitation, agencies and states. There is a low overall fit in regression 4 (Table 7) but some key variables are statistically significant in describing timing differences.

County median income, population density, and current and lagged precipitation are not statistically significant in this equation. County Sierra Club membership, as a density, is statistically significant at the 5 percent level for a two tailed test. The coefficient is positive giving the interpretation that Sierra Club members, or more generally people with an interest in prescribed fires and forest policy, have a significant impact on timing of prescribed fires. Here at the mean of county Sierra Club membership as a density there is an increase of one tenth of a month from the planned to the actual burn date.

In the robust regression (Table 7, regression 4) an F-test has a value of 5.61 which indicates the overall significance of agency dummy variables as a group. The only agency individually not statistically significant at least at the 10 percent level, compared to the BLM, is the NPS. The BIA, statistically significant at the 5 percent level, has burn dates that are longer by more than a month from when they planned to burn compared to the BLM. The USFS, on the other hand, burns a month quicker than the BLM.

The negative USFS coefficient may for example mean that the land agency, relative to the BLM, is planning dates well beyond what the agency thinks it would need to burn it by in order to meet their actual burn dates even in the face of protest. This explanation would mean there are political policies within the agencies to meet prescribed fire acreage goals. Therefore the USFS is planning on protests happening frequently and plan for them accordingly so they meet, or exceed, their goals.

The state dummy variables for Colorado, Idaho and Montana show statistical significance as a group at the 5 percent level with an F-test value of 3.62. The only statistically significant state individually is Colorado, this negative coefficient implies that Colorado controlled burns take place earlier when compared to Wyoming.

Table 7. OLS and Robust Regression of Actual – Planned Start Date.

Actual – Planned Start Date in Months	**Regression 3**	**Regression 4**
WUI	-0.1793	-0.1793
	(-0.71)	(-0.68)
County Median Income	-0.00001	-0.00001
	(-0.97)	(-1.07)
County Population Density	0.0016	0.0016
	(0.82)	(1.16)
County Sierra Club Membership/County Population	85.0201**	85.0201**
	(2.23)	(2.39)
Current Monthly Precipitation	0.1429	0.1429
	(0.70)	(0.69)
5 Month Lagged Precipitation	-0.4586	-0.4586
	(-0.97)	(-1.05)
BIA	1.3342**	1.3342**
	(2.45)	(1.96)
FWS	-1.1543	-1.1543*
	(-1.54)	(-1.71)
NPS	-0.5358	-0.5358
	(-0.78)	(-0.87)
USFS	-1.0329***	-1.0329***
	(-3.11)	(-2.98)
Colorado	-1.2332***	-1.2332*
	(-2.57)	(-1.91)
Idaho	-0.2182	-0.2182
	(-0.44)	(-0.32)
Montana	-0.5702	-0.5702
	(-1.19)	(-0.86)
Utah	-0.9482	-0.9482
	(-1.57)	(-1.23)
Constant	0.9919	0.9919
	(1.08)	(0.74)
Adjusted R^2	0.019	0.026

2147 Observations
(t-stats in paranthesis)
two-tailed t-stats
* 10% statistical significance
** 5% statistical significance
*** 1% statistical significance

Ordinary Least Squares for Proportion Acreage Difference

The difference between actual and planned acreage varies widely in this data. For example two fires in Colorado have an acre difference of 112 acres. The two fires have sizable differences in planned acres, which are 150 and 400 acres. They each burn roughly 112 acres more than originally planned but as a proportion there are large differences between these two fires. To control for this, proportion acreage difference is used to normalize this variable.

Regression 6 in Table 8 provides the results for a percent acreage difference dependent variable using a robust regression to correct for heteroskedasticity. The robust estimation controls for heteroskedasticity. In regression 5 heteroskedasticity was indicated by a Breusch-Pagan Test of 5744.41 giving a p-value of 0.0000.

The WUI does not have statistical significance in this model. County median income is statistically significant at the 10 percent level. The results indicate that as county median income increases there is a lower percentage change of acreage burnt. Because county median income is a proxy for education level, a slightly higher income may mean a better understanding of prescribed fire policy and henceforth a smaller change in the acreage burnt. The percent of the county belonging to the Sierra Club is not statistically significant in this regression. Current and five month lagged precipitation are not statistically significant. Precipitation, controlling for the fuel load of the burn area, appears to have very little to do with controlled burn acreage changes.

Table 8. OLS and Robust Regressions for Proportion Acre Difference.

Percent Acre Difference	**Regression 5**	**Regression 6**
	(OLS)	(Robust)
WUI	-0.0219	-0.0219
	(-0.59)	(-0.65)
County Median Income	-6.69e-06**	-6.69e-06*
	(-2.39)	(-1.84)
County Population Density	0.0001	0.0001
	(0.47)	(0.68)
County Sierra Club Membership/County Population	-1.5249	-1.5249
	(-0.27)	(-0.40)
Current Monthly Precipitation	0.1022***	0.1022
	(3.38)	(1.21)
5 Month Lagged Precipitation	-0.0815	-0.0815
	(-1.19)	(-1.40)
BIA	0.1408	0.1408
	(1.58)	(1.09)
FWS	-0.0302	-0.0302
	(-0.27)	(-0.34)
NPS	0.6552***	0.6552**
	(6.72)	(2.30)
USFS	-0.0971**	-0.0971**
	(-2.03)	(-2.42)
Colorado	0.1151	0.1151*
	(1.63)	(1.89)
Idaho	0.0462	0.0462
	(0.63)	(0.96)
Montana	0.0287	0.0287
	(0.41)	(0.58)

Table 8. OLS and Robust Regressions for Proportion Acre Difference (continued).

Percent Acre Difference	Regression 5	Regression 6
Utah	0.1193	0.1193
	(1.36)	(1.17)
Constant	0.1265	0.1265
	(0.93)	(0.98)
Adjusted R^2	0.044	0.051

1939 Observations
(t-stats in paranthesis)
two-tailed t-stats
* 10% statistical significance
** 5% statistical significance
*** 1% statistical significance

National land agencies are statistically significant as a group at the 5 percent level with an F-test of 3.63. The NPS and USFS are statistically significant at the 5 percent level individually. The NPS has a larger acre difference change than the BLM, whereas the USFS has a smaller acre difference change than the BLM. The NPS serves primarily tourists sightseeing and may therefore have last minute changes to acreage to accommodate less smoke and low risk burns. Although it may be argued that the NPS would decrease its acreage goals in the planning process, they are also likely to plan higher acreage goals in the event that they expect there to be fewer tourists are in the area. Also, larger prescribed fires cannot happen at the last minute because if a prescribed fire exceeds its planned area then the burn is considered a wildfire.

The state dummies are not statistically significant as a group with an F-test of 1.04.

In Chapter 4, the data showed large differences among agencies for WUI prescribed fires. The probit regression results, in Table 6, showed a strong statistical evidence for agency differences for the probability of a WUI prescribed fire. To control for possible differences interaction terms were used between agencies and WUI (e.g. WUI*USFS). When these additional variables were included on the right-hand side of the regression they showed no statistical significance as a group and reduced statistical significance of other variables.

Robustness Check: OLS Regressions with Interaction Variables

The probit regression (Table 6) provided insight regarding underlying factors influencing where an agency burns. That analysis showed that there was a higher probability of a WUI prescribed fire when the USFS is initiating the burn. Different national land agencies manage various types of land and therefore have different prescription goals. The USFS initiates 48 percent of their total acres in the WUI where as the FWS or BIA initiates less than 30 percent of their burns in the WUI (Chapter 4). To control for this possible agency difference in regressions of proportional acreage difference interaction variables between the agency dummy variable and the WUI designation is added to regressions 7 and 9 and replaces the agency intercept dummies in regressions 8 and 10. This formulation in regressions 8 and 10 allows for different agency behavior for WUI but not for non-WUI prescribed fires.

Table 9. Robust OLS of Actual – Planned Start Date.

Actual - Planned Date	**Regression 7**	**Regression 8**
WUI	-0.4963	0.2464
	(-0.68)	(0.52)
County Median Income	-0.00002	-0.00003
	(-1.07)	(-1.43)
County Population Density	0.0013	0.0013
	(1.01)	(1.02)
County Sierra Club Membership/County Population	82.9754**	98.6704***
	(2.33)	(2.78)
Current Monthly Precipitation	0.1324	0.1184
	(0.64)	(0.57)
5 Month Lagged Precipitation	-0.4171	-0.5945
	(-0.96)	(-1.34)
BIA	2.1356*	
	(1.82)	
FWS	-1.5712*	
	(-1.81)	
NPS	-0.0967	
	(-0.09)	
USFS	-1.4069**	
	(-2.25)	
Colorado	-1.1826*	-1.4642***
	(-1.85)	(-2.14)
Idaho	-0.1779	-0.4370
	(-0.26)	(-0.60)
Montana	-0.5434	-0.7011
	(-0.83)	(-0.98)
Utah	-0.8453	-1.1692
	(-1.12)	(-1.47)
BIA*WUI	-1.4611	0.6349
	(-1.06)	(0.86)
FWS*WUI	1.7814	0.2453
	(1.29)	(0.23)
NPS*WUI	-0.5579	-0.6342
	(-0.45)	(-0.87)
USFS*WUI	0.6401	-0.7638*
	(0.81)	(-1.79)
Constant	1.0789	0.9035
	(0.74)	(0.70)
Adjusted R^2	0.0287	0.0142

2147 Observations
(t-stats in paranthesis)
two-tailed t-stats
* 10% statistical significance
** 5% statistical significance
*** 1% statistical significance

Regression 7 presents results that imply significant differences among agencies. The F-test value of 1.76 and p-value of 0.1521 show that the interaction variables are not statistically significant as a group.

To simplify the analysis the agency dummies are deleted, allowing the Agency*WUI interaction variables to capture agency differences. These results (regression 10) are compared with those in regression 4 (Table 7).

The Agency*WUI interaction variables only have one statistically significant variable in regression 10, USFS*WUI, at the 10 percent level. These Agency*WUI interaction terms are statistically insignificant as a group with an F-test of 1.95 giving a p-value of 0.1188. Recall that the agency dummies were significant as a group (F-test statistic = 5.61) and two agency dummies were individually significant at the 5 percent level in regression 4. The larger adjusted R-squared in regression 4 relative to that in regression 8 also support the model formulation in regression 4.

This additional analysis shows agency differences are important as designed in regression 4 over the formulation in regressions 7 and 8. There do not appear to be important differences between agencies based on where they are burning in order to explain date changes for a prescribed fire. What has shown to be a strong predictor of date changes is the Sierra Club variable, which is statistically significant at the 5 percent level in regression 4 and the 1% level in regression 8. Interest in public lands policy, which is what the Sierra Club variable is controlling for, shows an actual start date being statistically farther out than the planned start date.

Table 10. Robust OLS Regressions for Proportion Acre Difference.

Proportion Acre Difference	**Regression 9**	**Regression 10**
WUI	-0.1105	-0.458
	(-1.22)	(-0.87)
County Median Income	-6.54e-06*	-5.64e-06*
	(-1.79)	(-1.64)
County Population Density	0.0001	0.0001
	(0.64)	(0.49)
County Sierra Club Membership/County Population	-1.9917	1.5227
	(-0.48)	(0.38)
Current Monthly Precipitation	0.1012	0.1058
	(1.18)	(1.23)
5 Month Lagged Precipitation	-0.8123	-0.0928
	(-1.38)	(-1.54)
BIA	0.0601	
	(0.32)	
FWS	-0.0544	
	(-0.45)	
NPS	0.6398	
	(1.48)	
USFS	-0.1605**	
	(-2.10)	
Colorado	0.1251**	0.0927
	(2.12)	(1.61)
Idaho	0.0504	0.0129
	(1.02)	(0.26)
Montana	0.0347	-0.0023
	(0.67)	(-0.05)
Utah	0.1312	0.1264
	(1.21)	(1.24)
BIA*WUI	0.1527	0.2337
	(0.58)	(1.29)
FWS*WUI	-0.0207	-0.0546
	(-0.12)	(-0.50)
NPS*WUI	0.0453	0.6480*
	(0.09)	(1.91)
USFS*WUI	0.1160	-0.0345
	(1.19)	(-0.72)
Constant	0.1624	0.0994
	(1.27)	(0.87)
Adjusted R^2	0.0516	0.0367

1939 Observations
(t-stats in parenthesis)
two-tailed t-stats
* 10% statistical significance
** 5% statistical significance
*** 1% statistical significance

Regression 9 presents the results for the proportion acre difference with the new interaction variables. The interaction variables, by themselves, are statistically insignificant. An F-test shows they are not statistically significant as a group with an F-test of 0.35 giving a p-value of 0.7911.

Although the Agency*WUI interaction variables are not statistically significant, the agency dummies are significant as a group at the 10 percent level with an F-test of 2.12 giving a p-value of 0.0952.

In order to further explore the effect of the agency the national land agency dummy variables are omitted (regression 8). This regression allows for different agency effects for WUI fires only. County median income stays statistically significant at the 10% level. In regression 6, the NPS coefficient is 0.6552 and in regression 10 the NPS*WUI has a coefficient of 0.6480. Both are statistically significant at the 5 percent level and have extremely close values. It is difficult to select between regression 7 and regression 8 given these results.

Instrumental Variables Regression for WUI

When a land agency decides to do a prescribed fire they must write up a proposal for the expected burn. Something they most likely decide at the same time, potentially creating a simultaneity bias, is whether or not to burn next to the wildland urban interface and then how large to make the burn. Because expected escape (Chapter 3) increases with size and because according to liability law the land agency is liable for escaped prescribed fires (Yoder 2004) the land agency may well decide to do smaller fires next to structures.

To control for this potential simultaneity bias in the proportion acreage difference analysis I use an instrumental variables regression. I instrument the WUI with year dummies for 2004 and 2005 and the other explanatory variables used in Table 9. There are two statistically significant variables at the 1 percent level and one statistically significant variable at the 5 percent level. This instrumental variable model does not appear to offer a significant improvement from the results in Table 9. The results can be seen in Appendix B in Table 15.

Summary

In the first probit regression, there was a negative relationship between the WUI and planned acres. An agency appears to attempt to decrease risk in the WUI especially when there are higher incomes (higher house values). Also, it is important to remember that the WUI is increasing over time, likely related to county population density. Finally, county Sierra Club membership was important in this equation to control for groups' environmental interest in prescribed fire policy for a national land agency as it might also relate to outdoor recreation and an overall interest in the outdoors.

There has been strong statistical significance of agency differences for all dependent variables, but there has not been strong statistical fixed effects of the state dummies.

One of the variables of interest, county Sierra Club membership, was not statistically significant for the proportion difference of acres but was statistically significant for the difference in the timing of a burn. Percent county Sierra Club memberships were found to increase the timing required of a burn, *ceteris paribus*. Other county demographic variables were statistically insignificant. In Chapter 3, I discussed that interest in public land agency policies was expected to increase the timing of a burn and this is supported by the results of the regression analysis.

Of additional interest at the end of this chapter were the interaction variables between agency dummies and the WUI. Models using Agency*WUI interaction terms did not show substantial improvement over models using agency dummies alone. Even though the WUI and non-WUI prescribed fires can vary vastly between agencies and general scope, agencies appear to be treating these WUI controlled burns consistently.

CHAPTER 6

CONCLUSION

This thesis developed a model of a land agency's decision to burn and empirically explained that theory using a panel data set of national land agencies in Colorado, Idaho, Montana, Utah, and Wyoming and their prescribed fires over the years 2003 to 2005. Multiple hypotheses were tested to explain an agency's decision to burn in the WUI, timing differences of a prescribed fire, and also acreage differences among agencies when burning prescribed fires.

Yoder (2004, 2005) concluded in multiple papers that liability law in the United States prohibits optimal prescribed fire policies specifically pertaining to the frequency an area is burned. What was missing in that research is a land agency's additional socio-economic considerations when it comes to timing delays. An example of the impacts of these concerns is a burn proposed to start in 1999 that was not completed for another 4 years (Chapter 4). Delays such as this cannot be contributed to weather delays but rather appear to be largely due to public pressure.

Using a theoretical model of maximizing a benefit to model a public land agency this thesis has shown empirically that land agencies respond to public pressure when it comes to whether or not to burn in the WUI. The data in Chapter 4 shows that over half of the total prescribed fires were in the WUI. A probit model shows an agency's decision to burn in the WUI depends on some key demographic variables. Population density of a county was a strong explanatory variable for a prescribed fire burning in the WUI. A higher Sierra Club membership, relative to county population, showed a statistically higher probability for a prescribed fire in the WUI. Their effect may be related to an increased interest in community protection along with animal habitat protection.

The way in which the timing of prescribed fires relates to formal protests is an area of research that has been overlooked. This thesis analyzes the timing of prescribed fires through Sierra Club membership of a county as an explanatory proxy for protests of a prescribed fire. The percent of a county belonging to the Sierra Club proved to be statistically significant, and the expected sign, in explaining timing differences of prescribed fires. With the data available, we could not establish a relation to protests and timing differences. That being said, there may be a time buffer built in to the proposed dates that control for expected protests. This is not unlikely because when an agency does not meet goals they can lose funding for projects (NIFC.gov).

Current precipitation was used to control for last-minute changes due to weather, but this variable was statistically insignificant for each regression analysis conducted. Lagged precipitation, controlling for fuel load, was also statistically insignificant explaining acreage or timing differences.

The difference between actual to planned acreage burned as a proportion was additionally analyzed. Again, Sierra Club membership of a county was not statistically significant in any of the regressions. Median income of a county, controlling for education level, had statistical significance, as county median income rose, acreage actually burnt, relative to what was planned to burn, decreased. Yoder’s (2005) findings that liability law caused a suboptimal solution to prescribed fires apply especially in the

WUI, and these results of income on acreage actually burnt are consistent with his findings.

Land agencies had statistical differences as a group for acreage differences and timing differences of controlled burns. The USFS burns fewer acres than they planned and the NPS burns more than they planned compared to the BLM.

Finally, WUI and non-WUI fire differences by agency were statistically insignificant in regard to proportion of acreage differences and also timing differences of prescribed fires. Using an interaction variable between the agency dummy and the WUI designation proved to provide little statistical improvement of models using only agency dummies.

Future Research

Although county Sierra Club membership was not a strong statistical explanatory variable for timing differences of prescribed fires there is another variable to explain this relationship. Formal protest records are kept in each prescribed fire file at each agency headquarters. The problem is that this data is not electronically available and would therefore be difficult to obtain on a large scale. A next step in explaining this issue might be to obtain that data and identify and test the effects of that variable. This data would entail essentially a series of case studies.

The interests of the formal protestors are also kept in each prescribed fire file. These interests range from smoke and air issues to habitat protection for wildlife.

Finally, prescribed fires are mandated by the NHFRA to increase protection in the WUI. Because this protection puts the national land agency at risk of liability should the fire escape, escaped prescribed fires might be of interest in the WUI and have an effect on overall timing and acreage differences.

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APPENDICES

APPENDIX A

DATA CORRELATION TABLES

Table 11. Correlations.

	County median income	**County population density**	**County Sierra Club membership**	**Sierra Club membership as county density**	**Current precipitation**	**5 month lagged precipitation**
County median income	1					
County population density	0.1492	1				
County Sierra Club membership	0.2626	0.5033	1			
Sierra Club membership as county density	0.5773	0.1594	0.5695	1		
Current precipitation	0.0179	-0.0158	0.0317	0.0315	1	
5 month lagged precipitation	0.0002	-0.0211	0.0619	0.0608	0.0711	1
Fiscal year	0.0897	0.0096	-0.0149	-0.0049	0.124	0.0453
Planned acres	-0.0299	-0.0203	-0.0351	-0.0592	-0.0132	-0.0027
Planned – actual acres	-0.0035	0.0017	-0.0053	0.0091	-0.0044	-0.0104
Planned – actual initiation month	0.0068	0.0002	-0.0109	0.045	0.0136	-0.0232
BIA	-0.1169	-0.0351	-0.0403	-0.0443	-0.04	-0.0592
BLM	0.0003	-0.0458	-0.0466	0.0088	-0.0243	-0.0232
FWS	-0.0097	0.1707	-0.0324	-0.0251	-0.0142	-0.0086
NPS	0.3278	0.0376	0.1507	0.2845	0.0029	-0.0053
USFS	-0.0698	-0.0217	0.0091	-0.0932	0.0462	0.0574
CO	0.1377	0.232	0.2189	0.0346	-0.0699	-0.0174
ID	-0.1592	-0.0259	-0.0901	-0.0938	0.0712	0.0265
MT	-0.1776	-0.1274	-0.0415	-0.072	0.0504	0.0196
UT	-0.1646	0.0179	-0.0636	0.0424	-0.0483	-0.0422
WY	0.4538	-0.0866	-0.0391	0.1506	-0.0375	-0.0042

	Fiscal year	Planned acres	Actual - planned acres	Actual – planned initiation month
Fiscal year	1			
Planned acres	-0.0795	1		
Actual – planned acres	0.0192	-0.2063	1	
Actual – planned initiation month	-0.0024	0.0224	0.0017	1
BIA	0.0127	-0.0402	0.0371	0.1061
BLM	-0.0215	0.1426	0.0137	0.0599
FWS	0.0225	-0.0205	0.0252	-0.0168
NPS	-0.0347	-0.0408	0.0135	0.0079
USFS	0.0169	-0.0698	-0.0469	-0.1052
CO	0.0324	-0.0295	0.0116	-0.0674
ID	-0.0306	0.0353	0.0044	0.0274
MT	-0.0098	-0.0945	-0.0058	0.0093
UT	0.0361	0.057	0.0375	-0.0076
WY	-0.0188	0.0807	-0.0461	0.0426

	BIA	BLM	FWS	NPS	USFS
BIA	1				
BLM	-0.1313	1			
FWS	-0.05	-0.0832	1		
NPS	-0.0577	-0.0961	-0.0366	1	
USFS	-0.406	-0.6756	-0.2574	-0.297	1
CO	-0.0909	0.0061	0.0551	0.0636	-0.0015
ID	-0.0244	-0.0579	-0.0284	-0.1137	0.1195
MT	0.1975	-0.187	-0.0127	-0.1218	0.0995
UT	-0.0772	0.1447	0.0272	0.1304	-0.1407
WY	-0.078	0.219	-0.0383	0.1348	-0.1788

	CO	ID	MT	UT	WY
CO	1				
ID	-0.2832	1			
MT	-0.3775	-0.4078	1		
UT	-0.1632	-0.1763	-0.235	1	
WY	-0.1834	-0.1981	-0.264	-0.1141	1

APPENDIX B

SUPPLEMENTARY REGRESSION TABLES

Regression 11 and 12 use county Sierra Club membership as opposed to county Sierra Club membership/county population. This gives a non-normalized result.

Table 12. Probit Regression for WUI Prescribed Fires.

	Regression 11	**Regression 12**
Planned Acres		-0.0003***
		(-7.14)
County Median Income	4.32E-06	3.20e-06
	(1.08)	(0.80)
County Population Density	0.0032***	0.0031***
	(3.65)	(3.60)
County Sierra Club Membership	0.0003***	0.0003***
	(2.70)	(2.61)
Current Precipitation	-0.0489	-0.0527
	(-0.99)	(-1.06)
5 Month Lagged Precipitation	0.0933	0.0982
	(0.83)	(0.86)
BIA	0.0659	0.0062
	(0.52)	(0.05)
FWS	-1.2601***	-1.3188***
	(-5.71)	(-5.97)
NPS	0.3043*	0.2305
	(1.80)	(1.36)
USFS	0.3875***	0.3473***
	(5.04)	(4.46)
Colorado	0.2712**	0.2257**
	(2.38)	(1.96)
Idaho	0.3495***	0.3301***
	(2.99)	(2.79)
Montana	0.1989*	0.1310
	(1.77)	(1.15)
Utah	0.1578	0.1484
	(1.14)	(1.06)
Constant	-0.3955*	-0.1991
	(-1.91)	(-0.95)
Pseudo R^2	0.0588	0.0788

2147 observatons
(t-stats in paranthesis)
2147 observations
two-tailed t-stats
* 10% statistical significance
** 5% statistical significance
*** 1% statistical significance

County Sierra Club membership is used instead of county Sierra Club membership/county population. This gives a non-normalized result.

Table 13. Proportion Acreage Difference from Actual to Planned..

Proportion Acreage Difference	**Regression 13**	**Regression 14**
WUI	-0.0251	-0.0251
	(-0.68)	(-0.75)
County Median Income	-7.79e-06***	-7.79e-06**
	(-3.29)	(-2.23)
County Population Density	-0.0001	-0.0001
	(-0.41)	(-0.75)
County Sierra Club Membership	0.0001	0.0001
	(1.65)	(1.05)
Current Monthly Precipitation	0.1003***	0.1003
	(3.32)	(1.21)
5 Month Lagged Precipitation	-0.0922	-0.0922
	(-1.34)	(-1.57)
BIA	0.1425	0.1425
	(1.60)	(1.10)
FWS	-0.0127	-0.0127
	(-0.11)	(-0.14)
NPS	0.6396***	0.6396**
	(6.56)	(2.31)
USFS	-0.0964**	-0.0964**
	(-2.02)	(-2.39)
Colorado	0.0973	0.0973*
	(1.37)	(1.73)
Idaho	0.0372	0.0372
	(0.51)	(0.78)
Montana	0.0137	0.0137
	(0.20)	(0.27)
Utah	0.1104	0.1104
	(1.28)	(1.11)
Constant	0.1767	0.1767
	(1.37)	(1.43)
Adjusted R^2	0.0451	0.0520

(t-stats in paranthesis)
1939 observations
two-tailed t-stats
* 10% statistical significance
** 5% statistical significance
*** 1% statistical significance

County Sierra Club membership is used instead of county Sierra Club membership/county population. This gives a non-normalized result.

Table 14. OLS Actual – Planned Start Date Regression.

Actual – Planned Start Date	**Regression 15**	**Regression 16**
WUI	-0.1498	-0.1498
	(-0.60)	(-0.57)
County Median Income	5.46e-06	5.46e-06
	(0.33)	(0.37)
County Population Density	0.0021	0.0021
	(0.99)	(1.41)
County Sierra Club Membership	-0.0001	-0.0001
	(-0.22)	(-0.27)
Current Monthly Precipitation	0.1518	0.1518
	(0.74)	(0.74)
5 Month Lagged Precipitation	-0.3619	-0.3619
	(-0.77)	(-0.82)
BIA	1.3358**	1.3358*
	(2.45)	(1.95)
FWS	-1.2552*	-1.2552*
	(-1.66)	(-1.86)
NPS	-0.4129	-0.4129
	(-0.60)	(-0.66)
USFS	-1.0771***	-1.0771***
	(-3.24)	(-3.13)
Colorado	-1.1260**	-1.1260*
	(-2.34)	(-1.72)
Idaho	-0.0614	-0.0614
	(-0.12)	(-0.09)
Montana	-0.3908	-0.3908
	(-0.82)	(-0.59)
Utah	-0.6616	-0.6616
	(-1.12)	(-0.87)
Constant	0.2093	0.2093
	(0.24)	(0.16)
Adjusted R^2	0.017	0.023

(t-stats in paranthesis)
2147 observations
two-tailed t-stats
* 10% statistical significance
** 5% statistical significance
*** 1% statistical significance

Table 15. Instrumental Variables Regression.

Proportion Acreage Difference	Regression 17
WUI	-0.5697
	(-0.78)
County Median Income	-6.57e-06**
	(-2.22)
County Population Density	0.0005
	(0.88)
County Sierra Club Membership	2.9275
	(0.35)
Current Monthly Precipitation	0.0954***
	(2.87)
5 Month Lagged Precipitation	-0.0688
	(-0.92)
BIA	0.1724*
	(1.68)
FWS	-0.2254
	(-0.79)
NPS	0.7287***
	(5.14)
USFS	-0.0132
	(-0.11)
Colorado	0.1747
	(1.61)
Idaho	0.1084
	(0.96)
Montana	0.0732
	(0.77)
Utah	0.1408
	(1.45)
Constant	0.3462
	(1.06)
Adjusted R^2	N/A

(t-stats in paranthesis)
1939 observations
two-tailed t-stats
* 10% statistical significance
** 5% statistical significance
*** 1% statistical significance