CHAPTER 15

ECONOMIC ANALYSIS OF FEDERAL WILDFIRE MANAGEMENT PROGRAMS

Krista M. Gebert, David E. Calkin,
Robert J. Huggett, Jr., and Karen L. Abt

1. INTRODUCTION

In the past two decades, there has been a significant increase in the number of acres burned by wildland fires and in the amount of money being spent to suppress these fires (Calkin et al. 2005a). With expenditures on suppression alone climbing to more than a billion dollars in four of the past seven years (2000-2006), the federal land management agencies are coming under ever increasing pressure by Congress and government oversight agencies to manage fire in a cost efficient manner. Economic analysis can benefit all fire-related programs and activities, and ignoring economic analysis in the wildland fire decision-making process, whether on a strategic or tactical level, can lead to wasted resources, poor outcomes, and higher-than-warranted expenditures.

A full economic analysis of federal land management agencies' wildfire programs would address activities undertaken: (1) before the fire, (2) during the fire, and (3) after the fire. The chapter begins with a description of the generally accepted model for evaluating wildland fire programs, the cost-plus-net value change or cost-plus-loss model. Though the cost-plus-loss model has been extended from its initial focus on presuppression to address all of these activities, most research to date has focused on a single aspect of the wildland fire program. We then turn to a discussion of where and how fire economics currently enters wildfire program decision making and indicate where additional applications are possible. We conclude with noting the issues and complications specific to conducting analyses of Federal wildfire management programs and suggestions for future research.

Early theoretical models of fire management determined the efficient level of the fire management program by minimizing the sum of program costs and fire damages (Headley 1916, Sparhawk 1925). As noted by Rideout and Omi (1990), these models have evolved over time to incorporate fire benefits as well. These cost-plus-net-value-change (C+NVC) models recognize that damages must be subtracted from benefits to arrive at the net gain or loss from a fire. The C+NVC model, whether set up to maximize net benefits or minimize costs plus loss, yields

T. P. Holmes et al. (eds.), The Economics of Forest Disturbances: Wildfires, Storms, and Invasive Species, 295–322.

the standard requirements for economic efficiency: the correct level of the program will be where the marginal benefits of fire management are equal to the sum of the marginal costs of fire management and the marginal net loss from fire.

Solving the C+NVC model determines the levels of presuppression inputs (the expenditures on placing equipment and personnel prior to a fire season) and in-season suppression inputs (Donovan and Rideout 2003). In addition, this model can be used to develop optimal levels of fuels treatment, prevention activities, and recovery and restoration activities (chapters 8 and 13-18 of this book). The main difficulty in implementing the C+NVC model, either from an operational standpoint or as an analytical tool, lies in determining net value change. The absolute change in human and natural values in the absence of management is unobserved. Even at the margin, the reduction in net damages from increasing suppression resources to fight a fire is unobserved or only observed with error. Further, the values-at-risk from wildfire include both market and non-market goods. Valuing non-market resources in monetary terms can be accomplished with well-established techniques such as travel cost or hedonic models. However, the effect of fire on these values is often unclear. These techniques are also data-intensive and time-consuming; qualities that make them ill-suited for use at the fire level where conditions change rapidly. Alternative techniques for monetizing non-market goods are discussed later in this chapter.

The net value change from wildfire can be broken down into three components, where each component reflects a change in a different set of values resulting from a potential condition where management does not try to influence fire behavior. The first is the monetized change in human values and services due to wildfire, such as damages to structures, timber losses, and damaged or destroyed recreation opportunities. The second is the monetized future change in ecosystem function and services from wildfire. As more suppression is applied, the beneficial effects of fire are diminished in fire-adapted ecosystems. However, reducing ecosystem damages from catastrophic fires by applying suppression inputs may increase future ecosystem function and services. A third element is the change in future fire management due to changes in fire regimes that may result from the over- or under-suppression of wildfire. For instance, if current suppression creates fuel buildups that depart from the natural fire regime and result in larger and more intense fires in the future, the discounted future value of increased suppression expenditures and damages should be included in NVC.

Applications of the C+NVC model over the years have primarily focused on budgeting for presuppression and determining the optimal level for suppression once the presuppression budget has been determined. For years, a computer-based, simulation modeling system based on the C+NVC model entitled NFMAS (National Fire Management Analysis System) was used by several federal and state fire management agencies to support fire program budget requests (NARTC 1997, Lundgren 1999). Another fire management tool developed using the C+NVC model was the Fire Economics Evaluation System (FEES) (Mills and Bratten 1982). The C+NVC-based systems were used primarily by agencies whose missions included resource utilization and commodity values. Different fire management tools (FIREPRO and FIREBASE) were used by the National Park Service and the Fish and Wildlife Service whose missions focused more on non-market values. These systems quantify staffing and financial requirements for fire management activities based upon an analysis of program workload and complexity including initial attack readiness, wildland fire use, and fuels management using historical information and average annual workload (Botti 1999).

Although these early fire management budgeting tools focused primarily on developing a presuppression budget, economic analysis is important for all fire-related programs and activities. In the pre-fire stage, economic analysis enters the wildland fire program through (1) land management planning, which provides overall direction for federal wildland management, (2) presuppression budgeting and the determination of location and quantities of physical fire suppression resources, and (3) fuel treatment programs to reduce fuel loads and thereby reduce damages from future wildfires. Economic analysis during the fire assists in tactical level planning during the season to determine appropriate management responses, such as allowing fires to burn for wildland restoration or suppressing the fire. In the post-fire stage, economic analysis is necessary to determine the appropriate level and type of expenditures for rehabilitation projects and for evaluating suppression performance ex-post after the season. Note that while we discuss these programs as though there are linear stages, one following the other, in fact the pre-fire stage is also the post-fire stage and, thus, may be better thought of as a circle. In addition, while we have defined the stages in reference to fire events, this is for discussion only, as a wildfire management program may involve activities of equal or greater consequence than the fires themselves.

2. ECONOMIC ANALYSIS OF ACTIVITIES BEFORE THE FIRE

Activities undertaken before a fire occurs include planning, pre-positioning of suppression resources, prevention, and fuels management (including mechanical fuel treatments and prescribed fire). Each of these is discussed in more detail below.

2.1 Planning

Current direction is for land management plans (long range planning documents that guide the management of individual forests) to recognize the role of fire, particularly where fire has historically been part of the ecological process. The Federal Fire Policy Implementation Strategy (USDA and USDI 2003) states that:

> Overall direction is provided to the wildland fire management program by land and resource management plans (L/RMP) . . .. The paramount policy is firefighter safety. Fire regime dynamics must also influence land and

> resource management objective development in the L/RMP. The L/RMP's desired future condition will incorporate the desired mix of Condition Classes by fire regime (page 9).

From the standpoint of desired future condition, wildland fire is seen as either a disturbance that can thwart attempts to achieve the desired future condition or a tool that can be used to make progress towards that condition.

More specific fire management plans (FMPs) identify and integrate all wildland fire management and related activities within the context of approved land management plans. Cost considerations in the FMP are most often addressed through the use of aggressive initial attack, to put out fires before they become large and costly, and appropriate management response (AMR) (discussed in section 3.2), which is suppose to consider both the costs of suppression and the values at risk. This is accomplished through the wildland fire situation analysis (WFSA) (also discussed in section 3.2) that is done at the time the fire escapes initial attack efforts.

In their 2004 report, the Strategic Issues Panel (Strategic Issues Panel 2004) stated that none of the L/RMPs that they looked at included any consideration of the costs of suppression. They further stated that because the plans were centered on gains, in terms of meeting desired future conditions, they provide little help in the area of loss aversion, which the panel felt was central to wildfire management. They recommended that the land management agencies "set policy and direction on agency land/resource management planning to incorporate cost management on large wildfires." In response to this, direction has been given to include discussions of the costs of suppression in these plans; however, there is currently no requirement for any sort of economic analysis.

Ideally, economic analysis at the planning stage would include some determination of values at risk, potential suppression expenditures, and possible benefits of wildland fire. Activities specifically addressed, in addition to suppression, would include (1) location and numbers of initial attack resources, (2) prevention and detection programs, and (3) fuel treatment options. Some of the new tools currently under development for budgetary planning (see FPA discussion in section 2.2) and wildland fire decision support (section 3.2) could be modified or extended for use in land management and fire management planning.

2.2 Resource Pre-Positioning

Pre-positioning of suppression resources has long been seen as a way to minimize damage from wildfires and constrain suppression costs. Having sufficient resources available to aggressively attack fires shortly after ignition was, and still is, seen as a way of keeping fires small, therefore mitigating damage and avoiding the large expenditures associated with attempting to suppress a wildfire once it has gotten large. Many initial attack planning models were designed around the general concept of C+NVC discussed in an earlier section and have included a mix of deterministic and simulation models. These models have recently come under criticism for a number of reasons including their inability to account for nonmarket values and to deal with more complex fire situations since they are based on average fire seasons and single fire starts.

More recent models have attempted to address some of these shortcomings. The California Fire Economics Simulator (CFAS) (Fried 2006) was designed to deal with these more complex situations including multiple fire starts, drawdown of resources, differing fire fighting tactics, and so forth. The Fire Program Analysis system (FPA 2005), currently being developed by the federal land management agencies, uses cost effectiveness analysis to better account for the value of non-market resources. The numbers, types, and locations of suppression resources prior to the fire season can be optimally determined by cost effectiveness analyses to evaluate the efficient allocation of presuppression resources by optimizing weighted acres managed, a non-monetized measure based on expert opinion.

2.3 Prevention

Wildland fire prevention programs are aimed at reducing the occurrence of human-caused wildland fires and mitigating the damages caused by those fires that do occur (reducing the cost plus loss of wildfires). In fact Stephen Pyne has been quoted as saying "an ounce of prevention is worth several pounds of fire damages and fire suppression expenses" (Doolittle and Donaghue 1991).

Prevention programs are targeted at ignition sources with the potential to cause the greatest losses. This potential is evaluated through an assessment of risk, hazard, and value with these terms being defined as follows: (1) risk–uses, human activities, or events with the potential to result in wildfire ignitions, (2) hazard–the fuels and topography of an area, and (3) values–natural or developed areas where losses by fire are unacceptable. These elements are evaluated using historical fire information and are tied to land management and fire management plans. Prevention programs include such things as education programs aimed to prevent human-caused fires by changing people's behavior (such as the Smokey Bear program), visible patrolling of fire prone areas, and enforcement of fire regulations and ordinances. Early fire detection is also part of the fire prevention program by catching fires before they become a problem, thereby reducing losses. Removal of hazardous fuels around homes and using fire resistant materials when building homes in fire prone areas can help homeowners protect their property when fires do occur and the Firewise communities program has been developed to aid communities and homeowners in designing safer communities and homes (NIFC 2007, Firewise Communities 2007).

Research related to the economics of fire prevention, however, is virtually nonexistent and has primarily focused on identifying areas at risk from wildland fires to aid in the planning process or reducing the risk of wildland fires through the use of fuels management (next section). Some research has been done related to wildland arson fires, which is described in detail in chapter 7.

2.4 Fuels Management

The development of the National Fire Plan produced an increased interest in the economics of fuel reduction treatments as land managers attempt to deal with high fuel loads. The primary purpose of the Healthy Forest Restoration Act of 2003 (Public Law 108-148) is: "to reduce wildfire risk to communities, municipal water supplies, and other at-risk Federal lands through a collaborative process of planning, prioritizing, and implementing hazardous fuel reduction projects." Therefore, the USDA Forest Service (USFS) and the U.S. Department of Interior (DOI) have committed to a significant increase in hazardous fuel treatments. The cost and effectiveness of different fuel treatments in different forest settings must be understood, however, before desired outcomes can be achieved in a fiscally responsible manner,

While there is overall agreement that fuel treatments can affect fire behavior by reducing intensity and/or size of fire (Graham et al. 2004, Agee and Skinner 2005, Stephens and Moghaddas 2005), it is still uncertain whether the benefits of these treatments outweigh the costs. Benefits include the restoration of ecosystem health, which is difficult to value, as well as avoided costs such as reduced suppression expenditures and reduced property damage. Costs of fuel treatments, whether prescribed burning or mechanical treatments, have been shown to be a function of fuel loads, slope, and fuel treatment location (wildland urban interface or not) (Berry and Hesseln 2004, Berry et al. 2006, Calkin and Gebert 2006, Skog et al. 2006). In addition, administrative factors and managers' risk aversion were found to influence treatment costs (González-Cabán and McKetta 1986, González-Cabán 1997). Nearly all empirical studies have found that larger treatments (in acres) result in lower costs per acre (Rideout and Omi 1995, Berry and Hesseln 2004, Calkin and Gebert 2006). However, data on actual fuel treatment costs, for both mechanical and prescribed burning treatments, are limited, in spite of continued interest in this topic for more than 20 years (González-Cabán and McKetta 1986, Cleaves et al. 1999, Berry and Hesseln 2004, Calkin and Gebert 2006).

Recently, simulations have been used to augment actual data, including simulations of mechanical fuel treatment costs (Skog et al. 2006), and simulation combined with data to calculate reductions in suppression costs from implementing landscape scale fuel treatment projects (Prestemon et al. 2007, Mercer et al. 2007). Decision support systems have also been developed that use optimization to select the spatial arrangement and timing of treatments to best meet ecosystem and economic objectives (Jones et al. 1999, Barrett et al. 2000, Chew et al. 2003). Additional research is needed to develop methods to evaluate the overall costs and benefits from fuel treatments.

3. ECONOMIC ANALYSIS OF ACTIVITIES DURING THE FIRE

Suppression expenditures have dominated discussion of wildland fire management in recent years because of the huge amounts of money being spent to suppress those fires that escape initial attack efforts. Expenditures by the USFS alone have topped $1 billion in four of the last seven years (2000-2006) and suppression expenditures are making up an increasingly larger part of the overall USFS budget. This has brought increased scrutiny of the suppression program and has led to a greater emphasis on cost containment and the need to make economical decisions.

There are two times that suppression activities and expenditures are analyzed. First is when the fire escapes initial attack and a plan for suppression must be developed (currently called the wildland fire situation analysis or WFSA). The second time is when suppression is analyzed after the fire (ex post). The information gained from these ex post examinations can then be applied during the suppression planning process in subsequent years. So, while the WFSA process happens first for any given fire, in the context of the fire program, we first analyze suppression expenditures ex post and then apply the lessons learned to individual fires during the suppression planning process. Therefore, we discuss ex post suppression cost analysis first followed by suppression planning for individual fires.

3.1 Ex Post Suppression Cost Analysis

The ex post analysis of suppression costs can be performed at several different levels of the organization (national, regional, forest level, individual fire level) and can differ in the types of costs being analyzed. The analysis can focus solely on the money spent to suppress the fire or it can attempt a broader focus, by trying to assess the costs and benefits of wildland fire and suppression activities. Due to the magnitude of the money being spent to suppress wildfires as of late, much of the recent work has focused on analyzing suppression expenditures themselves.

In the past, wildfire suppression expenditures were justified as a necessary part of the business of land management. However, recent severe fire seasons and their associated costs have spurred interest in the costs and value of wildland fire suppression programs, and government oversight agencies such as the Office of Management and Budget and the Government Accountability Office (GAO) have responded with increased scrutiny of Federal wildland fire programs.[1]

[1] GAO was formerly known as the General Accounting Office. Examples of reports that address wildland fire programs include Wildfire Suppression: Funding Transfers Cause Project Cancellations and Delays, Strained Relationships, and Management Disruptions (GAO 2004) and Wildland Fire Management:Timely Identification of Long-Term Options and Funding Needs is Critical (GAO 2005) and Wildland fire Mangement: Lack of Clear Goals or a Strategy Hinders Federal Agencies' Efforts to Contain the Costs of Fighting Fires (GAO 2007). These and other reports are available online at www.gao.gov.

In 2003, the USFS, the DOI, and the National Association of State Foresters issued a Large Fire Cost Action Plan recognizing that:

> Our culture and incentive system are not oriented toward reducing the costs of large fires. Currently, the local Agency Line Officer and Incident Commander have three primary objectives: 1) ensure firefighter and public safety, 2) suppress the wildland fire, and 3) respond to community needs (USFS, DOI, and NASF 2003, page 7).

While the Action Plan recommended that cost containment be elevated so that it is commensurate with these other objectives, a more recent USFS conference concluded that cost containment is essential; however, it is not a primary objective of fire management.[2] Specifically, "cost management is a very significant component of meeting fire suppression objectives, but is not an overriding goal in itself." The Action Plan also states that managers should "expend only those funds required for the safe, cost effective suppression of the wildfire incident," a difficult task to accomplish without sufficient knowledge of the cost and benefits of suppression actions.

Cost containment of wildland fire suppression expenditures generally refers to controlling expenditures on wildfires. Figure 15.1 shows federal spending on wildfire suppression by each federal agency from FY 1995–2005 (adjusted for inflation to 2005 dollars). The USFS has been responsible for 73 percent of expenditures on average. All of the Federal agencies have experienced statistically significant

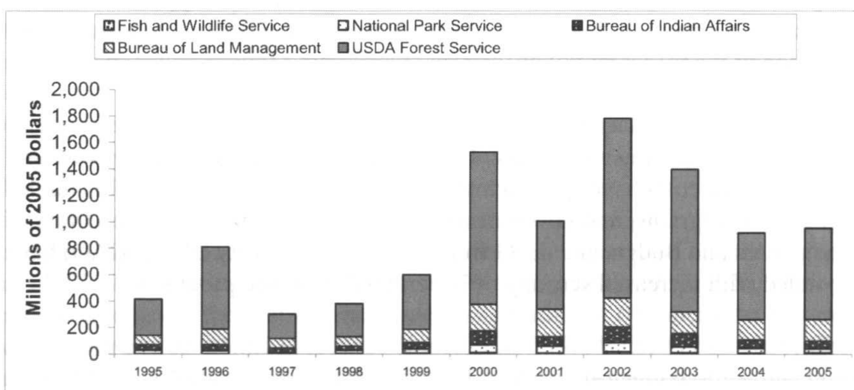

Figure 15.1. Wildland fire suppression expenditures (2005$) by Federal land management agencies, FY 1995-2005.

[2] The Pulaski conference was a weeklong workshop sponsored by USDA Forest Service, Fire and Aviation Management, designed to develop foundational doctrine with regard to wildfire suppression (USDA Forest Service 2005).

upward trends in expenditures. The National Park Service and the Bureau of Land Management experienced annual real growth rates of approximately 10 percent. The Bureau of Indian Affairs was slightly lower, with an annual real growth rate of 8 percent, and USFS suppression expenditures grew at an annual real rate of more than 12 percent. However, the Fish and Wildlife Service experienced an annual growth rate of 61 percent, though in total their share of suppression expenditures was extremely small. This large percentage change is largely due to extremely low expenditures for the Fish & Wildlife Service in FYs 1996 and 1997 rather than substantial increases in later years (the rate of growth would have been 13 percent if those years were excluded).

The Budget Object Classification Code (BOC) system is used by the federal government to record financial transactions when obligations are first incurred. Analysis at the BOC level indicates no substantial change in expenditures by general categories such as personnel versus supplies and services over the past decade (table 15.1). These percentages remained fairly stable during the period from FY 1996-2004 even though suppression expenditures were rising. Expenditures on contracts are often blamed for rising expenditures. However, it does not appear that the percentage of expenditures in this category has shown much change since 1996. Unfortunately, there is insufficient data for an analysis of the effect of contractual services on suppression expenditures. Even at its finest scale, BOC information does not provide sufficient detail for a full analysis of suppression expenditures (data discussion later in the chapter).

A variety of explanations for the increased severity and associated expenditures on wildland fire suppression have been suggested including fuel accumulation due to past fire suppression (Arno and Brown 1991, Arno et al. 2000), a more complex fire fighting environment due to expanding private development within the wildland urban interface (WUI) (Snyder 1999), and severe drought

Table 15.1. Suppression expenditures by category for fiscal years 1996-2004

Fiscal Year	Salaries and benefits	Travel	Contracts	Supplies	Other
	Percent				
1996	34	4	54	9	0
1997	39	2	49	8	2
1998	38	5	44	13	0
1999	29	3	60	7	1
2000	29	4	58	8	1
2001	33	4	54	9	1
2002	28	3	59	9	0
2003	31	3	61	5	0
2004	37	3	56	4	0

caused by long term weather phenomena (Agee 1998, Westerling et al. 2003, Calkin et al. 2005a, Westerling et al. 2006). Numerous fire reviews have tried to assess the reasons for increased suppression expenditures (USDA Forest Service 1995a, 1995b, NAPA 2002, Strategic Issues Panel 2004), citing many of the same reasons for the rise in expenditures. However, concerns remain that Federal suppression resources are not being utilized efficiently, perhaps due to an incentive system that discourages risk taking and thus encourages excessive resource use (for example, chapter 16).

Using regional fire suppression data, Calkin et al. (2005a) provide evidence that recent increases may largely be weather-driven. Using data from FYs 1971-2002, they state that unit expenditures (cost per area burned) have not been increasing, but the number of large fires, the average size of large fires, and the overall area burned have been increasing along with the increase in expenditures. Additionally, they showed that area burned can be modeled successfully using current and past regional drought indices and that area burned and suppression expenditures are highly correlated (r = 0.70). They state that "simply put, suppression expenditures increased and became erratic when acres burned increased and became erratic" (fig. 15.2). Since 1995 the USFS has experienced an annual rate of growth in total suppression expenditures of around 15 percent. However, unit expenditures during that time have not significantly increased (fig. 15.3). Westerling et al.

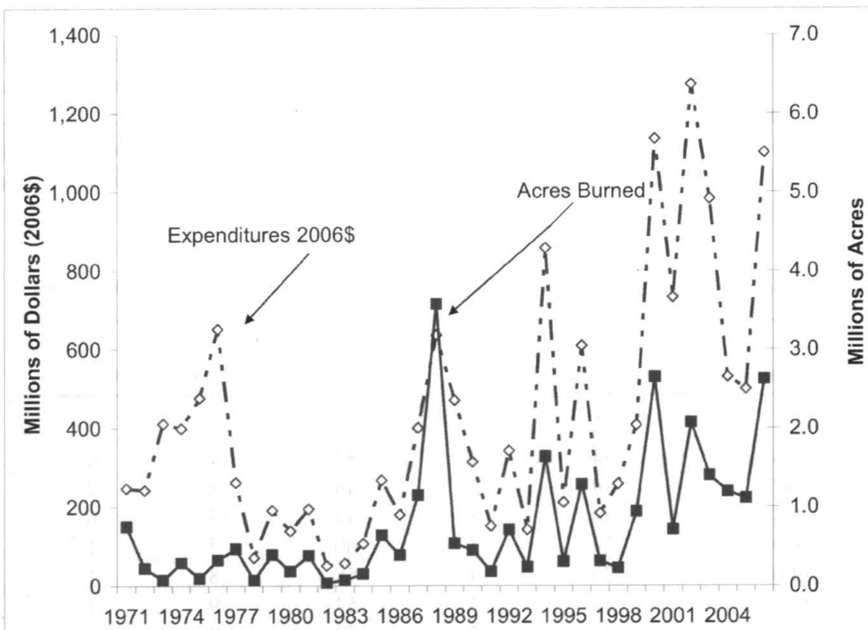

Figure 15.2. Forest Service wildland fire suppression expenditures (2006$) and acres burned for large fires (>= 300 acres), FY 1971-2006.

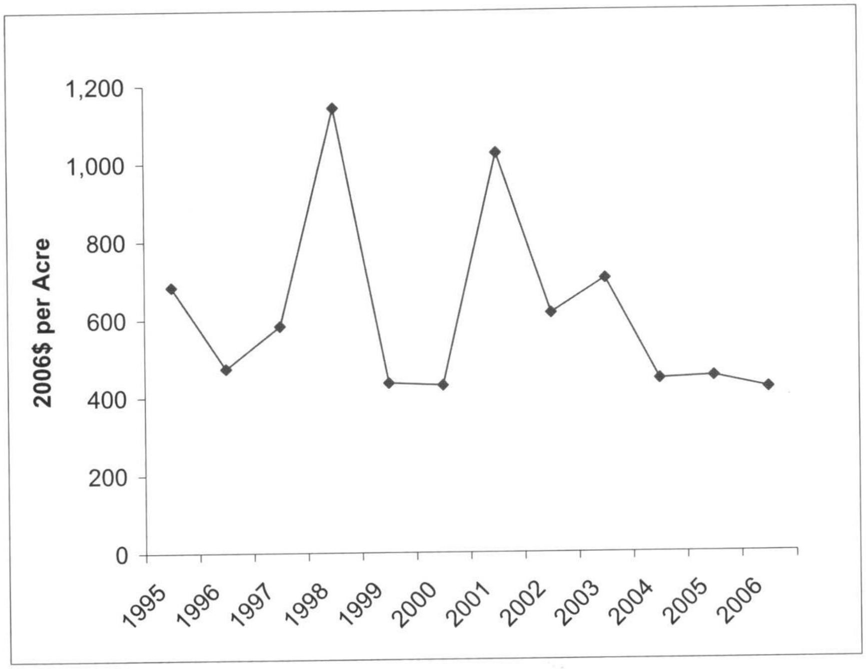

Figure 15.3. Forest Service suppression expenditures per acre burned.

(2006) also provides evidence that the severe fire seasons, and related expenditures, of recent years may be largely climate driven.

A study by Canton-Thompson et al. (2006) focused on how incident management teams (IMTs) make suppression decisions regarding the resources used on the fire and other factors affecting suppression expenditures. Data for this study were collected from 48 in-depth interviews with Incident Management Team (IMT) command and general staff personnel from federal, state, and local land management agencies throughout the country. Some important cost issues that have emerged from preliminary analysis of the interviews include increased risk aversion on the parts of both IMTs and agency administrators, the inability of IMTs to make major cost decisions due to limited decision space defined by the Agency Administrator, the significant increase in rules and regulations in recent years which constrain the IMT's flexibility, external (often politically driven) decisions about what resources to use on a particular fire, contracting-related issues including quality of contracted resources, and substantial increase in technology and associated expenditures.

Several studies have found evidence of the link between increasing values at risk, especially in terms of private property, and suppression expenditures. Gebert et al. (2007) compiled a large dataset of USFS fires in the Western United States (USFS Regions 1 through 6) to estimate a predictive suppression expenditure model and did find that higher home values within 20 miles of a fire ignition increase total fire cost. Among the other variables found to influence cost were variables associated with extreme fire behavior and drought conditions, with increasing fire intensity levels and energy release component values associated with higher costs. Liang et al. (in review) studied USFS fire suppression expenditures for 100 large fires occurring in the Northern Region of the USFS and the influence of 16 potential spatial factors including fire size and shape, private properties, public land attributes, forest and fuel conditions, and geographic settings. They found fire size and private land had a strong effect on suppression expenditures.

Economic analysis is not solely concerned with the expenditures for suppressing wildfires but also with the efficient use of resources to achieve the maximum benefit to society, taking into account both costs and benefits. A key in evaluating the economic efficiency of wildfire suppression is estimating the benefit of suppression efforts, a component of net value change in the C+NVC model. This involves identifying the area that would have burned had suppression activities not occurred. Once the appropriate analysis area for value change estimation is determined, the problem then turns to valuing those resources at risk. In the current wildfire environment, private resource values and public infrastructure are frequently the strategic drivers of suppression decisions both from a values at risk standpoint, and often, more importantly, a political standpoint (NAPA 2002, Canton-Thompson et al. 2006, Gebert et al. 2007, Liang et al. (in review)). Structures, specifically homes at the wildland-urban interface, are among the most obvious values at risk from wildland fire. Threatened structures significantly influence suppression decisions and are potentially the most difficult, dangerous, and expensive resource to protect.

Many of the resource values protected by wildland fire suppression are non-market resources, and monetizing these values can be difficult and controversial. Although non-market valuation techniques such as contingent valuation, travel cost models, and hedonic pricing have identified monetary values for many non-market resource values (Englin et al. 2001, Koteen et al. 2002, Hesseln et. al. 2003 and 2004, Huggett 2003, Donovan et al. 2007), issues specific to individual locations of a given large fire, uncertainty associated with the effect of fire on the resources of interest, and fire induced changes to the forest ecosystem over time make application of these results very challenging. A direct monetary comparison of values protected with suppression expenditures has not been done. When monetized values are not available or appropriate, alternative valuation methods can be used, including cost effectiveness analysis, reference to historic range of variation, analytical hierarchical processes, and other expert opinion based methods. However, each of these methods has associated challenges.

3.2 Suppression Plan for an Individual Fire

Once a fire has started, the first role of economic analysis is to help choose the appropriate management response. Historically, federal land management agencies have drawn a distinct line between (1) suppression responses, where the manager's objective is to contain/control the fire as soon as possible with maximum efficiency and with the highest regard for safety (USDA Forest Service 2005) and (2) management responses referred to as wildland fire use, where the manager's objective is to monitor the fire to "protect, maintain, and enhance resources and, as nearly as possible, allow it to function in its natural ecological role (paraphrased) (USDA and USDI 2005).[3] One of the reasons for this distinction is that managing a wildfire for resource benefits (wildland fire use) subjects the fire to National Environmental Policy Act (NEPA) requirements which must be completed prior to designating the fire as wildland fire use (FSM 5103.2-6). Suppression fires have no NEPA requirements as they are considered an emergency situation.

The Wildland Fire Use Implementation Procedures Reference Guide (USDA and USDI 2005) restates current policy outlining the separation of suppression and wildland fire use:

> "Only one management objective will be applied to a wildland fire. Wildland fires can either be managed for resource benefits or suppressed…Human-caused wildland fires will be suppressed in every instance and will not be managed for resource benefits…(page 3)

In 1995, the Federal Wildland Fire Management Policy and Program Review was completed and introduced the concept of appropriate management response (AMR) where fires receive "management actions appropriate to conditions of the fire, fuels, weather, and topography to accomplish specific objectives for the area where the fire is burning" (Zimmerman 1999). In the 2001 review of the 1995 Federal Fire Policy (Interagency Federal Wildland Fire Policy Review Working Team 2001) one recommendation was to "base responses to wildland fires on approved fire management plans and land management plans, regardless of ignition source or the location of the ignition", and they advised that barriers to achieving this goal should be eliminated. They also stated that "determination of the appropriate response will include an evaluation of such factors as risks to firefighter and public health and safety, weather, fuel conditions, threats, and values to be protected."

With the rising costs of wildland fire suppression, increasing emphasis is being placed on the use of AMR. It is hoped that the use of less aggressive suppression strategies, where appropriate, will result in suppression expenditure savings (OIG 2007). Though AMR does not represent a change in policy, as it was first introduced in the 1995 Fire Policy (USDA and USDI 1995), there has been some

[3] As of 2006, only 29 percent of FS wilderness areas had approved fire management plans that allowed for the option of wildland fire use somewhere within their boundaries (Carol Miller, Pers. Comm., Aldo Leopold Wilderness Research Institute, January 20, 2004).

confusion surrounding its implementation, and steps are being taken to clarify the existing policy. Several directives and clarifying guidelines were issued in FY 2007 to clear up the confusion surrounding appropriate management response and to give the forest land managers guidance as to the different types of suppression tactics available for both wildland fire use and suppression (USDA Forest Service 2006, USDA and USDI 2007, NRCG 2007). These documents emphasize that even though the distinction is still made between wildland fire use and suppression (with only one of these management objectives allowed on a fire), the tactics used on the fire may not be much different. With both types of fires, except for special circumstances dictated by law, land management plans, or fire management plans, "managers have the options of suppressing a fire, confining a fire with natural barriers, conducting a large scale burnout to contain a fire, or even just monitoring the fire" (USDA Forest Service 2006, page 2).

Two separate processes have been used for evaluating response strategies depending upon whether the fire is deemed suitable for wildland fire use or the fire should be actively suppressed. When deemed a wildland fire use fire, a Wildland Fire Implementation Plan is used to examine the available response strategies. See Wildland Fire Use Implementation Procedures Reference Guide (USDA and USDI 2005) for an explanation of these plans. The role of economics in developing the response strategy is largely subjective. Users are asked to exercise their judgment in evaluating the values at risk. These values include "ecological, social, and economic effects that could be lost or damaged by a fire" and are assessed with a risk scale of low, moderate, or high. Additionally, proximity of the fire to these values is assessed with a scale of distant, moderate, or adjacent.

If a fire is not extinguished in the first operational period (usually no more than 24 hours), either through the use of initial or extended attack forces, and a larger and more complex firefighting organization is deemed necessary, the fire is declared "escaped" and a wildland fire situation analysis (WFSA) begins. Through this process, the land management agency evaluates alternative suppression strategies defined by different goals and objectives, suppression costs, impacts on the land management base, and values at risk (MacGregor and Haynes 2005). Although the analysis provides a mechanism for valuing resources at risk, these valuations are subjective and have only taken into account resource values on public lands. Though land managers are aware that private resource values play a large role in fire management decisions, "there is no clear direction pertaining to the preparation of WFSA's and the inclusion of private land and community values (structures and infrastructure) as an element of benefit cost relating to suppression costs when WUI or occluded communities are at risk from a fire originating on National Forest land."[4]

In an effort to alleviate some of the aforementioned problems, the Wildland Fire Decision Support System (WFDSS: http://wfdss.nwcg.gov) is currently in

[3] Fire and Aviation Management briefing paper dated April 23, 2003, available from the authors.

development and beta testing. Use of the new system has become a required process for fires deemed to be of national significance during the 2007 fire season (per a letter from Chief Abigail Kimbell, June 11, 2007). For fires expected to cost more than $5 million but less than $10 million, the use of the new WFDSS system is recommended. For fires expected to cost more than $10 million, its use is required. In 2006 two promising components for WFDSS were prototyped; a new fire spread probability prediction application (FSPro–Fire Spread Probability) and an application that uses FSPro outputs to assess values at risk (RAVAR–Rapid Assessment of Values at Risk).

The Fire Spread Probability model, FSPro, is a new fire modeling tool that calculates the probability of fire spread from a current fire perimeter or ignition point for a specified time period assuming no suppression. The model simulates the 2-D growth of the fire across the landscape (fuels & topography) using a computationally efficient form of the *FARSITE* calculations (see Finney 1998 for a description of the *FARSITE* program). FSPro differs from *FARSITE* in that it simulates fire growth for thousands of possible weather scenarios using the latest recorded perimeter (or point). Different weather possibilities are developed statistically using the data from the weather station (fuel moisture, wind speed and direction). FSPro can assist managers to prioritize fire fighting resources based on probabilities of fire spread by assessing a fire's growth potential, informing appropriate strategy and tactics development and allocation of resources

RAVAR identifies the primary resource values threatened by ongoing large fire events. RAVAR is directly integrated with the new FSPro model to identify the likelihood of different resources being affected by an ongoing fire event. RAVAR spatially maps the location of threatened structures, public infrastructure, and high priority natural and cultural resources. RAVAR was designed to assist agency administrators, incident managers, and fire planners develop wildfire suppression strategies by rapidly identifying and quantifying the significant resource values and relative threat to those resources from an ongoing fire event. Additionally, RAVAR can help support development of the Wildland Fire Situation Analysis (WFSA) and could be used to help prioritize large fire needs during periods when area command is convened.

Developing estimates of suppression expenditures, the cost portion of the C+NVC model, is another critical piece of the economic analysis of the fire stage. Estimated expenditures on fire suppression in the WFSA system were based upon cost estimates using either historical cost per acre or by selecting the fire fighting resources to be used and arriving at an aggregate cost for these resources. Both methods are flawed. Per acre cost estimates are often based upon a small number of fires, whose characteristics might vary dramatically from the fire in question. Aggregating fire suppression resources does not take into account the large overhead costs often associated with these larger fires. Suppression cost functions estimated ex-post could be used by the analyst during the fire to forecast expenditures.

Donovan et al. (2004) used regression analysis to identify variables affecting suppression expenditures for 58 fires that occurred in Oregon and Washington in 2002. The only significant variables were fire size and terrain with measures of housing density, a focus of this study, not showing up as a significant predictor of costs. Steele and Stier (1998) developed a series of regression equations to estimate suppression costs for Wisconsin wildfires managed by the State Department of Natural Resources. Significant variables included final fire size and burning index. González-Cabán (1984) estimated suppression expenditures based on the number and type of the different resources used on the fire, and they found considerable variation among fires and regions of the country. With the exception of Steele and Stier (1998) all of these studies indicated they were hindered by the lack of reliable data.

The Stratified Cost Index (SCI) was developed in FY 2006 and has been adopted as a performance measure and incorporated into the WFDSS system. Per the Chief's letter of June 11, 2007, its use is required on all fires estimated to cost more then $5 million. The Index determines average suppression costs based on fire characteristics such as fuel types, fire intensity, topography, region, and values at risk. After the characteristics of a current fire are entered into the WFDSS system, the user is given a range of possible expenditures for fires with similar characteristics and shown where the cost of their fire falls within that range. If the cost of the current fire falls within one of the upper ranges, it is likely that the fire will be reviewed post-season (Gebert et al. 2007).

4. ECONOMIC ANALYSIS OF ACTIVITIES AFTER THE FIRE

Activities that occur after the fire include rehabilitation and restoration, performance measures, and impact studies. Impact studies are specifically addressed in chapter 8; thus, they are not further addressed here.

4.1 Rehabilitation and Restoration

Following containment of a large fire, immediate rehabilitation and restoration projects may be required to prevent additional catastrophic resource damage from floods, erosion and landslides. Burned Area Emergency Response (BAER) teams are sent to assess and initiate the required rehabilitation work. Working under tight timelines, BAER teams are required to demonstrate that the value of resources to be protected by emergency response treatments exceeds the costs of the treatments. However, several limitations compromise effective calculation of values-at-risk including: (1) inadequate scientific knowledge and data to support calculation of the market values, (2) methods to account for non-market resources are controversial and difficult to apply, and (3) the extent of the area that should be included as at-risk is unknown. Currently, the final calculations developed within BAER assessments are best described as estimates based upon professional judgment (Robichaud et al. 2000).

Calkin et al. (2006) note that studies addressing how fire and post-fire erosion affect values at risk are limited and that benefit transfer issues (i.e., the transferability of study results from one location or resource value to another) reduce the applicability of these studies. They have proposed new methods to assess the economic value of treatments designed to protect non-market values at risk. These recommendations were developed through a study that included direct field observation, surveys with BAER personnel, a literature review of non-market resources typically encountered, and recognition of the challenges of the BAER analysis environment. They concluded that an implied minimum value approach may be most appropriate for valuing the nonmarket values associated with the BAER environment. Implied minimum value is defined as valuation based on the amount that is spent to avoid a negative outcome and the amount of risk reduction received for the money spent.

4.2 Performance Measures

Alternative performance metrics are under development in response to a current push towards evaluating the performance of government programs, including wildland fire suppression. Conference Report on HR 4818, Consolidated Appropriations Act, 2005 required the Secretaries of Interior and Agriculture to promptly establish appropriate performance measures for wildland fire suppression and develop a report on interagency performance measures planned for implementation in fiscal year 2006. This report was completed and highlighted the work being done for the WFDSS system and the SCI as potential performance measures. This was in line with the report by the Strategic Issues Panel on Large Fire Costs (2004), which recommended that federal agencies responsible for wildland fire should "Develop and use a benefit cost measure as the core measure of suppression cost effectiveness." In addition, the Forest Service Strategic Plan (USDA Forest Service 2004) outlines a performance measure, under the goal of "reducing the risk of catastrophic wildfire", of the "percent of large fires in which the values of resources protected exceeds the cost of suppression" with a target of 55 percent in FY 2008.

An approach that follows the benefit-cost logic of the C+NVC model would relate suppression expenditures to the values of the resources protected, not the area that did burn. Wildland fire suppression efforts could be seen as economically justified if the values protected are worth at least as much as the amount of money spent to suppress the fires. Therefore, an outcome-based performance measure should compare suppression expenditures to estimated resource value change on unburned areas that would have burned in the absence of suppression activities.

Calkin et al. (2005b) used break-even analysis to compare the value of structures threatened, identified from cadastre data, against suppression expenditures for two fires during the 2003 fire season in Montana. The authors examined an interface fire adjacent to the city of Missoula (the Black Mountain Fire) and a more rural fire that began in a USFS designated wilderness area (Crazy Horse Fire). The authors found that suppression expenditures on the Black Mountain Fire were economically justified by the value of structures protected if these efforts reduced the potential fire perimeter a modest amount (approximately 50 percent). However, the potential fire perimeter for the Crazy Horse Fire would have had to be considerably larger (greater than 180 percent) than the actual fire perimeter for the associated suppression expenditures to be economically justified from a structures at risk standpoint. The vegetation types and fire regime condition class associated with the Crazy Horse Fire suggest that the impact of the fire on non-market values at risk may not have been severe and in some cases may have provided ecological benefits. However, fire managers familiar with this fire suggested that the intermix of private and state timberlands adjacent to federal lands may have triggered an aggressive and, therefore, expensive suppression response.

Another performance measure currently being used by the USFS and in the development stage for the DOI is the stratified cost index (SCI) discussed in section 3.2. SCI assesses a variety of factors that influence suppression expenditures, including energy release component. Regression equations were developed to estimate fire specific expenditures given fire characteristics such as size, the fire environment, values at risk, and location (Gebert et al. 2007). When used as a performance measure, the SCI regression equations are used to calculate the expected suppression cost of a large fire (>= 300 acres) given its characteristics. The expected cost is then compared to actual suppression expenditures and a list of outliers (fires where actual cost is one or two standard deviations above expected cost) is provided to USFS Fire and Aviation Management. This effort will result in a common metric to normalize large fire suppression cost which can be used for reviews, evaluations, planning, and reporting.

The development of new performance metrics for the wildland fire program reflect the need for information on what the increasing levels of spending are buying the American taxpayer. With the wide array of possible reasons for escalating expenditures, economic analysis becomes very complex, and the answer as to whether or not these rising expenditures are the result of uncontrollable events and increased values at risk or due to overspending is difficult to assess.

5. DATA CONSTRAINTS

Any analysis of the economic efficiency of the fire program requires accurate expenditure data. Historically, this data has been difficult to obtain. Large fires most often involve multiple agencies, with multiple systems for recording both expenditures and fire characteristics, and little or no linkage between systems, making identification of actual costs difficult. Changes in record keeping over time make time series analysis difficult. Fire expenditure data is plagued by accounting practices that were not designed to aid systematic investigations of suppression expenditures. Problems are associated with specific fire expenditures as well as expenditures at national or regional levels.

The Budget Object Classification Code (BOC) system is used by the federal government to record financial transactions when obligations are first incurred. Unfortunately, the current BOC system makes it nearly impossible to obtain useful information on specific high cost items, such as contractual services. In FY 2002, $412 million of the $1.19 billion fire suppression expenditures were categorized as "Contractual Services–Other". Determining exactly what this money was spent on requires accessing the detailed transaction records. The "Contractual Services–Other" category includes such items as caterers, showers, tents, toilets, and can even include aviation contracts, if someone miscodes these to the more general category (Schuster et al. 1997, page 16). More specific BOC categories could provide valuable information in discerning the effectiveness of cost containment measures.

Another problem associated with tracking costs at a regional level is the mismatch between the tracking of expenditures versus fire activity. Expenditures are tracked according to the administrative unit spending the money, not according to the geographic area were the activity occurred. For example, if the USFS Northern Region sends crews to fight a fire in the Southern Region (as often happens early in the season or when suppression resources are scarce), in the financial system these expenditures are ascribed to the Northern Region (the resource's home unit), not the Southern Region. However, the fire activity is associated with the Southern Region. This is not an issue when dealing with aggregate national expenditures or even fire-specific expenditures (which can be traced to the region where the fire activity occurred through the accounting code), but it can cause problems for regional analyses. To assess the extent of this disconnection, we analyzed a subset of fires for which expenditures could be obtained both by and in region, which consisted of collecting accounting code-level expenditures from the financial system by region. The accounting code, in many instances, can be used to discern where the fire occurred (in-region expenditures) since the accounting code for a specific fire contains a region designator. The financial system also contains a field for the home unit of the resources charging to the fire (the by-region designator). An analysis of fires from FY 1995–2006 shows that the percentage of regional expenditures spent on fire activity in that region ranged from a high of 95 percent for Region 5 to a low of 11 percent for Region 10 (table 15.2). This process is being changed in FY 2007, with fire expenditures being tracked in the financial system according to the region where the fire started.

Other problems occur with fire-specific data. Until recently, reliable data on fire suppression expenditures on individual large fires has not been widely, or easily, available for several reasons. First, prior to FY 2004, obtaining actual individual fire suppression expenditures on an interagency basis was difficult

Table 15.2. Percent distribution of fire organization expenditures by location of fire, FYs 1995-2006

The In-By Problem	Fire Location (in)									
	Region									
1995-2006	1	2	3	4	5	6	8	9	10	Total
	Percent									
Regional (by)										
Region 1	91.5	0.9	1.4	2.0	1.3	0.8	1.7	0.2	0.2	100
Region 2	2.0	84.6	1.3	6.3	1.8	1.4	2.4	0.2	0.1	100
Region 3	2.1	1.2	82.8	5.2	3.4	1.9	3.3	0.1	0.0	100
Region 4	1.7	1.2	1.2	91.4	2.4	0.7	1.1	0.1	0.2	100
Region 5	1.5	0.9	2.3	3.7	94.8	1.3	-4.6	0.0	0.2	100
Region 6	1.2	0.7	0.9	1.8	1.6	92.3	1.1	0.0	0.4	100
Region 8	2.7	0.8	0.8	3.8	2.1	3.1	86.4	0.2	0.0	100
Region 9	9.0	2.4	1.9	11.2	4.8	6.7	6.8	57.0	0.1	100
Region 10	28.7	4.5	2.2	31.6	8.8	8.8	4.3	0.2	10.9	100
Region 13+	5.6	7.5	6.6	43.8	13.2	14.9	7.6	0.5	0.3	100

Note: Region 13 refers to non-region specific expenditures, such as national contracts, and the National Interagency Fire Center in Boise, ID.

due to different accounting systems and processes for tracking suppression expenditures. As of FY 2004, the federal land management agencies began using "FireCode" as a response to the House Appropriations Subcommittee for National Fire Plan Agencies' directive to "develop a method to standardize fire incident financial coding for fire suppression and subsequent emergency stabilization.... to provide the capability to effectively track and compile the full cost of a multi-jurisdictional fire suppression effort" (NIFC 2004). Second, matching actual fire-specific expenditures with fire characteristic information has been problematic due to the lack of a common field between (and among) fire characteristic data-bases and the financial systems used to track fire-specific expenditures. However, in FY 2007, the FireCode was made a required field in the Forest Service's fire occurrence database (NIFMID—National Interagency Fire Management Integrated Database), which should alleviate this problem in the future. Another problem associated with tracking suppression expenditures on individual fires, at least for the USFS, is that smaller fires (< 300 acres) are lumped into one FireCode for a region or forest. This makes it impossible to ascertain expenditures on individual small fires or analyze the costs and characteristics of small fires, as opposed to large fires.

Finally, a great deal of information is collected on large wildland fires, but there is not a single data repository or a common fire identifier among fire information systems. For instance, the USFS's fire occurrence database, NIFMID, contains fire occurrence information for fires reported by the USFS. The ICS-209 Incident

Status Summary is used for reporting information on "incidents of significance" (USDA Forest Service 2004b) and contains additional information on individual fires that differs from that found in NIFMID, such as resources used, structures threatened or destroyed, and so forth. However, there is no common identifier at this time between the two systems, so it is difficult to compile information from the two systems. Additionally, the DOI has its own fire occurrence reporting system, actually two systems, one for the Fish and Wildlife Service (Fire Management Information System—FMIS) and another for the other three agencies (Wildland Fire Management Information—WFMI). Both of these systems collect slightly different information on individual fires.

Steps are being taken to make access to fire data easier and more reliable. An interagency fire occurrence database (Fire Occurrence Reporting System—FORS) is currently being developed by the USFS and DOI. The vision for this system is that it will contain a set of critical and common fire occurrence data elements to be used by the interagency fire community. This will allow for easier access to fire information across the federal agencies, but at this point, is not expected to include non-federal wildland fires. Additionally, the FAMWEB (Fire and Aviation Management Web Applications) web site will soon contain a data warehouse for accessing historical fire, weather, and aviation databases through a variety of query and report options, and it will also contain some information related to non-federal wildland fires. The site will also include a web-based geospatial tool to enable users to view interactive maps of fire-related information. However, at this point it is unclear whether these systems will attempt to improve the quality of the data available or will just provide easier access to current systems.

Currently, much of the wildland fire data available is non-spatial. However, the technology and information to collect data more conducive to spatial analysis has grown considerably in recent years, and fire data that could be analyzed from a spatial perspective would likely help provide answers that non-spatial data cannot. Examples of such information would be location and type of fire line, ownership patterns, property and resource values adjacent to the fire perimeter, and location of past fuel treatment areas. Additionally the production of spatial data describing vegetation, wildland fuel, and fire regimes at a 30-meter grid resolution by the LANDFIRE project (Landscape Fire and Resource Management Planning Tools Project) will provide consistent data across the United States that can be used to help analyze fire management activities (Rollins et al. 2006).

6. DIRECTIONS FOR FUTURE RESEARCH

Though research to date has made substantial progress in many areas related to the economics of wildland fire management, there are still many unanswered questions. For example, little is currently known about the relative effectiveness of alternative suppression resources (e.g., crews versus aircraft). If aircraft are deemed too expensive, what are the consequences of using other less expensive, but perhaps less effective, resources? The encroachment of populations into the wildland-urban interface is often blamed for the rising costs of suppression, but more research is needed to examine this issue and its cost implications. Statements have been made that 50 to 95 percent of the money to suppress fires is spent protecting structures in the wildland urban interface (USDA Forest Service 1995b, OIG 2006), but no research studies have been done to assess the validity of these statements. Policy, both formal and informal, and social/political pressures can affect the suppression strategies and resources used on a fire, but how much of a factor this plays is largely unknown.

Fire suppression is, however, only one piece of the fire program. The effectiveness of fuel treatments on affecting fire behavior and suppression expenditures is largely unknown. The theoretical relationship of presuppression and suppression is largely untested. In reality, does more spending on presuppression lead to less spending on suppression? How do suppression expenditures relate to expenditures on emergency rehabilitation and stabilization? Does more wildland fire use mean less money spent on suppression and/or fuel treatments? Further research into these issues is needed to create a wildland fire program that will reduce the risk from catastrophic wildland fire in a cost efficient and effective manner.

7. REFERENCES

Agee, J.K. 1998. The severe weather wildfire—too hot to handle. Northwest Science. 71(1):153-156.

Agee, J.K., and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. Forest Ecology and Management 211(1-2):83-96.

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

Arno, S.F., D.J. Parsons, and R.E. Keane. 2000. Mixed-severity fire regimes in the Northern Rocky Mountains: Consequences of fire exclusion and options for the future. In: Wilderness Science in a Time of Change Conference - Volume 5: Wilderness Ecosystems, Threats and Management, D.N. Cole, S.F. McCool, W.T. Borrie, and J. O'Loughlin (compilers). Proceedings RMRS-P-15-VOL-5. USDA Forest Service, Rocky Mountain Research Station.

Barrett, T.M., J.G. Jones, and R.H. Wakimoto. 2000. Forest Service spatial information use for planning prescribed fires. Western Journal of Applied Forestry 15(4):200-207.

Berry, A.H., and H. Hesseln. 2004. The effect of the wildland-urban interface on prescribed burning costs in the Pacific Northwestern United States. Journal of Forestry 102(6):33-37.

Berry, A.H., G. Donovan, and H. Hesseln. 2006. Prescribed burning costs and the WUI: Economic effects in the Pacific Northwest. Western Journal of Applied Forestry 21(2):72-78.

Botti, S.J. 1999. The National Park Service wildland fire management program. In: Proceedings of the Symposium on Fire Economics Planning and Policy: Bottom Lines, A. González-Cabán and P.N. Omi (coordinators). Gen. Tech. Rep. PSW-GTR-173. USDA Forest Service, Albany, CA. p. 7-13.

Butry, D.T., D.E. Mercer, J.P. Prestemon, J.M. Pye, and T.P. Holmes. 2001. What is the price of catastrophic wildfire? Journal of Forestry 99 (11):9-17.

Calkin, D.E., and K.M. Gebert. 2006. Modeling fuel treatment costs on Forest Service lands in the western United States. Western Journal of Applied Forestry 21(4):217-221.

Calkin D.E., K.M. Gebert, J.G. Jones, and R.P. Neilson. 2005a. Forest Service large fire area burned and suppression expenditure trends, 1970-2002. Journal of Forestry 103(4):179-183.

Calkin, D.E., K. Hyde, K. Gebert, and J.G. Jones. 2005b. Comparing resource values at risk from wildfires with Forest Service fire suppression expenditures: Examples from 2003 Western Montana wildfire season. RMRS-RN-24WWW. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Calkin, D.E., J.G. Jones, and P.R. Robichaud. 2006. Improving BAER calculations of values at risk. Available online at http://www.firescience.gov/projects/05-1-1-09/05-1-1-09_final_report.pdf.

Canton-Thompson, J., B. Thompson, K. Gebert, D. Calkin, G. Donovan, and G. Jones. 2006. Factors affecting fire suppression costs as identified by incident management teams. Res. Note RMRS-RN-30. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Chew, J., J.G. Jones, C. Stalling, J. Sullivan, and S. Slack. 2003. Combining simulation and optimization for evaluating the effectiveness of fuel treatments for four different fuel conditions at landscape scales. In: Proceedings of the Eighth Symposium of Systems Analysis in Forest Resources, G.J. Arthaud and T.M. Barrett (eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands. p. 35-46.

Cleaves, D.A., T.K. Haines, and J. Martinez. 1999. Prescribed burning costs: Trends and influences in the National Forest System. In: Proceeding of the Symposium on Fire Economics Planning, and Policy: Bottom Lines, A. González-Cabán and P.N. Omi (coordinators). Gen. Tech. Rep. PSW-GTR-173. USDA Forest Service, Albany, CA. p. 277-288.

Doolittle, L., and L.R. Donaghue. 1991. Status of wildfire prevention evaluation in the United States. Research Paper NC-298. USDA Forest Service, North Central Forest Experiment Station, St. Paul, MN.

Donovan, G.H., and D.B. Rideout 2003. A reformulation of the cost plus net value change (c+nvc) model of wildfire economics. Forest. Science. 49(2):318-323.

Donovan, G.H., Champ, P.A., and D.T. Butrey. 2007. Wildfire risk and housing prices: A case study from Colorado Springs. Land Economics 83(2):217-233.

Donovan G., P. Noordijk, and V. Radeloff. 2004. Estimating the impact of proximity of houses on wildfire suppression costs in Oregon and Washington. In: Proceedings of 2nd symposium on fire economics, planning and policy: A global view. Cordoba, Spain, April 19-22, 2004 [CD Rom].

Englin, J., J. Loomis, and A. González-Cabán. 2001. The dynamic path of recreational values following a forest fire: A comparative analysis of states in the intermountain West. Canadian Journal of Forest Research 31(10):1837-1844.

Finney, M.A. 1998. FARSITE: Fire area simulator - Model development and evaluation. Research Paper RMRS-RP-4. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT.

Firewise Communities. 2007. Available online at http://www.firewise.org/index.php. Last accessed July 17, 2007.

FPA—Fire Program Analysis. 2005. Available online at http://www.fpa.nifc.gov/Library/EOWEP_V2_2005_02.pdf. Last accessed June 16, 2005.

Fried J.S., J.K. Gilless, and J. Spero. 2006. Analyzing initial attack on wildland fires using stochastic simulation. International Journal of Wildland Fire 15:137-146.

GAO (United States General Accounting Office). 2004. Wildfire suppression: Funding transfers cause project cancellations and delays, strained relationships, and management disruptions. General Accounting Office Report GAO-04-612, Washington, D.C.

GAO (United States Government Accountability Office). 2005. Wildland fire management: Timely identification of long-term options and funding needs is critical. Government Accountability Office Report GAO-05-923T, Washington, D.C.

GAO (United States Government Accountability Office). 2007. Wildland fire management: Lack of clear goals or a strategy hinders federal agencies' efforts to contain the costs of fighting fires. Government Accountability Office Report GAO-07-655, Washington, D.C.

Gebert K.M., D.E. Calkin, and J. Yoder. 2007. Estimating suppression expenditures for individual large wildland fires. Western Journal of Applied Forestry 22(3):188-196.

González-Cabán, A. 1984. Costs of firefighting mopup activities. Research Note PSW-367. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkley, CA.

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(4):116-121.

Graham, R.T., S. McCaffrey, and T.B. Jain. 2004. Science basis for changing forest structure to modify wildfire behavior and severity. Gen. Tech. Rep. RMRS-GTR-120. USDA Forest Service, Rocky Mountain Research Station, Ogden, Utah.

Headly, R. 1916. Fire suppression district 5. USDA Forest Service, Washington, D.C.

Hesseln, H., J.B. Loomis, and A. González-Cabán. 2004. Comparing the economics effects of fire on hiking demand in Montana and Colorado. Journal of Forest Economics 10(1):21-36.

Hesseln, H., J.G. Loomis, A. González-Cabán, and S. Alexander. 2003. Wildfire effects on hiking and biking demand in New Mexico: A travel cost study. Journal of Environmental Management 69:359-368.

Huggett Jr., R.J. 2003. Fire in the wildland-urban interface: An examination of the effects of wildfire on residential property markets. Ph.D. Dissertation, North Carolina State University, Raleigh.

Interagency Federal Wildland Fire Policy Review Working Team. 2001. Review and update of the 1995 federal wildland fire management policy. Available online at http://www.nifc.gov/fire_policy/history/index.htm.

Jones, G., J. Chew, and H. Zuuring. 1999. Applying simulation and optimization to plan fuel treatment at landscape scales. In: Proceedings of the Symposium on Fire Economics, Planning and Policy: Bottom Lines, A. González-Cabán and P.N. Omi (coordinators). Gen. Tech. Rep. PSW-GTR-173. USDA Forest Service, Pacific Southwest Research Station, Albany, CA. p. 229-236.

Kent, B., K. Gebert, S. McCaffrey, W. Martin, D. Calkin, E. Schuster, J. Martin, H. Bender, G. Alward, Y. Kumagai, P. Cohn, M. Carroll, D. Williams, and C. Ekarious. 2003. Social and economic issues of the Hayman fire. In: Hayman fire case study, R. Graham (ed.). Gen. Tech. Rep. RMRS-GTR-114. USDA Forest Service, Ogden, UT.

Koteen, J., S. Alexander, and J. Loomis. 2002. Evaluating benefits and costs of changes in water quality. Gen. Tech. Rep. PNW-GTR-548. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Liang, J., D.E. Calkin, K.M. Gebert, T.J. Venn, and R.P. Silverstein. (In review). Spatial factors influencing large wildland fire suppression expenditures. International Journal of Wildland Fire.

Lundgren, S. 1999. The national fire management analysis system (NFMAS) past 2000: A new horizon. Pp 71-78. In: Proceedings of the Symposium on Fire Economics, Planning and Policy: Bottom Lines, A. González-Cabán and P.N. Omi (coordinators). Gen. Tech. Rep. PSW-GTR-173. USDA Forest Service, Pacific Southwest Research Station, Albany, CA.

MacGregor, D.G., and R.W. Haynes. 2005. Integrated research to improve fire management decisionmaking. Gen. Tech. Rep. PNW-GTR-63. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Mercer, D.E., J.P. Prestemon, D.T. Butry, and J.M. Pye. 2007. Evaluating alternative prescribed burning policies to reduce net economic damages from wildfire. American Journal of Agricultural Economics 89(1):63-77.

Mercer, D.E., J.M. Pye, J.P. Prestemon, D.T. Butry, and T.P. Holmes. 2000. Economic effects of catastrophic wildfires. Final Report to Joint Fire Science Program, Ecological and Economic Consequences of the 1998 Florida Wildfires.

Mills, T.J., and F.W. Bratten. FEES: Design of a fire economics evaluation system. Gen. Tech. Rep. PSW-65. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Albany, CA.

NAPA (National Academy of Public Administrators). 2002. Wildfire suppression: Strategies for containing costs.

NARTC (National Advanced Resource Technology Center). 1997. NFMAS: National fire management system. Unpublished training manual, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT.

NIFC (National Interagency Fire Center). 2004. FireCode System User's Guide. Available online at http://www.nifc.gov/news/firecode/userguide/guide_toc.html. Last accessed July 17, 2007.

NIFC (National Interagency Fire Center). 2007. Prevention and education website. Available online at http://www.nifc.gov/preved/index.html. Last accessed July 17, 2007.

NRCG (Northern Rockies Coordination Group). 2007. Appropriate management response summary for the Northern Rockies. Available online at http://www.fs.fed.us/r1/fire/nrcg/BulletinBoard/AMRsummary.pdf.

OIG (Office of Inspector General). 2006. Audit report: Forest Service large fire suppression costs. Report Number 08601-44-SF.

Prestemon, J.P., K.L. Abt, and R.J. Huggett, Jr. 2007. A feasibility assessment of a methodology to evaluate the costs and benefits of large scale treatment programs under conditions approximating real-world fire, climate, vegetation and economic conditions. Final Report for Joint Fire Science Program Grant #06-3-2-24. Available online at http://www.firescience.gov/JFSP_Search_Results_Detail.cfm?project_id=06-3-2-24&fy_funded=2006. Last accessed July 27, 2007.

Rideout, D.B., and P.N. Omi. 1990. Alternate expressions for the economic theory of forest fire management. Forest Science 36(3):614-624.

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

Robichaud, P.R., J.L. Beyers, and D.G. Neary. 2000. Evaluating the effectiveness of post-fire rehabilitation treatments. Gen. Tech. Rep. RMRS-GTR-63. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Rollins, M.G., and C.K. Frame (eds.). 2006. The LANDFIRE prototype project: Nationally consistent and locally relevant geospatial data for wildland fire management. Gen. Tech. Rep.RMRS-GTR-175. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Schuster, E.G., D.A. Cleaves, and E.F. Bell. 1997. Analysis of USDA Forest Service fire-related expenditures 1970-1995. Research Paper PSW-RP-230. USDA Forest Service, Pacific Southwest Research Station, Albany, CA.

Skog, K.E., R.J. Barbour, K.L. Abt, E.M. Bilek, F. Burch, R.D. Fight, R.J. Huggett, Jr,, P.D. Miles, E.D. Reinhardt, and W.D. Shepperd. 2006. Evaluation of silvicultural treatments and biomass used for reducing fire hazard in western states. Research Paper FPL-RP-634. USDA Forest Service, Forest Products Lab, Madison, WI.

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

Sparhawk, W.N. 1925. The use of liability ratings in planning forest fire protection. Journal of Agricultural Research 30(8):693-762.

Steele, T.W., and J.C. Stier. 1998. An economic evaluation of public and organized wildfire detection in Wisconsin. International Journal of Wildland Fire 8(4):205-215.

Stephens, S.L., and J.J. Moghaddas. 2005. Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree mortality in a California mixed conifer forest. Forest Ecology and Management 215:21-36.

Strategic Issues Panel. 2002. Large fire suppression costs: Strategies for cost management. Report to the wildland fire leadership council from the strategic issues panel on fire suppression costs. Available online at http://www.fireplan.gov/reports/2004/costmanagement.pdf.

USDA and USDI (United States Department of Agriculture and United States Department of Interior). 1995. Federal wildland fire management policy and program review, final report.

USDA and USDI (United States Department of Agriculture and United States Department of Interior). 2003. Interagency strategy for the implementation of federal wildland fire management policy. Available online at http://www.nifc.gov/fire_policy/pdf/strategy.pdf.

USDA and USDI (United States Department of Agriculture and United States Department of the Interior). 2005. Wildland fire use implementation procedures reference guide. Available online at http://www.fs.fed.us/fire/wfsa/wildland_fire_use_guide.pdf.

USDA and USDI (United States Department of Agriculture and United States Department of the Interior). 2007. Direction to leaders: federal fire and aviation program. Available online at http://www.nifc.gov/nicc/administrative/nmac/strategy/NMAC_Apx_1.pdf.

USDA Forest Service. 1995a. Fire suppression costs on large fires: A review of the 1994 season. USDA Forest Service, Fire and Aviation Management, Washington, D.C.

USDA Forest Service. 1995b. Strategic assessment of fire management in the USDA Forest Service. USDA Forest Service, Washington, D.C.

USDA Forest Service. 2004. USDA Forest Service strategic plan for fiscal years 2004-2008. FS-810. USDA Forest Service, Washington, D.C.

USDA Forest Service, Fire and Aviation Management. 2005. Wildfire suppression: Foundational doctrine. Available online at http://www.fs.fed.us/r2/blackhills/news/vnr/releases/doctrinefinala.pdf.

USDA Forest Service. 2006 (draft). Appropriate management response (AMR): Guide book for National Forests. Available online at http://www.nafri.gov/pages/imm.htm.

USFS, USDI, and NADF (USDA Forest Service, U.S. Department of Interior, and National Association of State Foresters). 2003. Large Fire Cost Reduction Action Plan. Available online at http://www.fs.fed.us/fire/management/action_plan/cost_reduction.html. Last accessed June 6, 2005.

Westerling, A.L., A. Gershunov, T.J. Brown, D.R. Cayan, and M.D. Dettinger. 2003. Climate and wildfire in the Western United States. Bulletin of the American Meteorological Society. 84(5):595-604.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increases western U.S. forest wildfire activity. Science 313:940-943.

Wiitala, M.R., and D.W. Carlton. 1994. Assessing long-term fire movement risk in wilderness fire management. Proceedings of the 12th Conference on Fire Forest Meteorology. October 26-28, Jekyll Island Georgia. Soc. Am. Foresters, Bethesda MD.

Zimmerman, G.T. 1999. Cost of appropriate management response. In: Proceedings of the symposium on fire economics, planning and policy: Bottom lines, A. González-Cabán and P.N. Omi (coordinators). Gen. Tech. Rep. PSW-GTR-173. USDA Forest Service, Pacific Southwest Research Station, Albany, CA.