Wildland Fire Management Program Benefit-Cost Analysis
A Review of Relevant Literature

Prepared by the Office of Policy Analysis

June 2012

U.S. Department of the Interior

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1. Introduction

Federal fire program budgets, wildfire frequency and intensity, and associated losses have been a concern for many years. More recently, demographic changes, climate change, and other factors, have increased these concerns. This report, which focuses on the Department of the Interior's (DOI's) fire programs, reviews the wildland fire literature to provide a background on key issues, based on six topics relevant to fire program management:

- Policy,
- Budget trends,
- Measuring performance,
- Role of economic analysis,
- Wildland fire models, and
- Data availability.

Four DOI Bureaus – Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA), U.S. Fish and Wildlife Service (FWS), and National Park Service (NPS) – have wildland fire management responsibilities that they integrate into their stewardship missions. DOI's Office of Wildland Fire (OWF) develops Department-wide policies and allocates appropriated funds to the bureaus.

2. Policy Issues

Wildland fire management policies and land management have evolved considerably since 1886, when the U.S. Army began to patrol the newly created National Parks.[1] Writing in 2006, Robert Keiter described federal fire policy as uncoordinated and fragmented – "a welter of organic statutory provisions, environmental protection mandates, annual budget riders, site-specific legislation, judicial decisions, policy documents, management plans, and diverse state statutory prohibitions."[2]

DOI and the U.S. Department of Agriculture (USDA) Forest Service (USFS) have historically cooperated with each other and with state, tribal, and local agencies on fire suppression efforts.[3] Over time, this collaboration has grown to include improving wildland fire preparedness. Efforts to develop a more comprehensive federal/nonfederal wildland fire preparedness strategy grew with the 1995 Federal Wildland Fire Policy and continue through the current efforts to develop a National Cohesive Wildland Fire Management Strategy to identify the most effective and affordable long-term approach for addressing wildland fire problems, as required by Congress in the 2009 Federal Land Assistance, Management, and Enhancement (FLAME) Act.[4]

Federal/nonfederal wildland fire policy has its roots in the 1910-1935 fires, which triggered federal policies advocating total fire suppression.[5] The Weeks Act of 1911 and the Clarke-McNary Act of 1924 initiated cooperative assistance to states, enlisting their collaboration in fire suppression.[6] The 1926 "10-Acre Policy" mandated suppressing all fires before they reach 10 acres in size. In 1935, the "10 a.m. Policy" was implemented, requiring all fires to be extinguished before 10 a.m. the morning following their first report.[7] The 10 a.m. Policy called for the "fast, energetic, and thorough suppression of all fires in all locations, during possibly dangerous fire weather…Failing in this effort, the attack each succeeding day will be planned and executed with the aim, without reservation, of obtaining control before 10 o'clock of the next morning."[8] This reflected the philosophy that all wildland fires represented unacceptable threats, and the view that it would be cost effective to aggressively suppress small wildfires before allowing them to grow.[9] The objective was to gain control during the relatively cool and calm conditions of night and early morning.[10]

By the 1950s, evidence mounted that the suppression-dominated policy was adversely effecting wildlife habitat and creating forests with greater risk of severe wildfires.[11] Aldo Leopold's 1963 seminal report, *Wildlife Management in the National Park*, represented a turning point.[12] Federal agencies began to consider the advice of scientists who questioned excluding fire from ecosystems. By the 1970s, there was a federal effort to reintroduce fire through planned burning.[13] By 1995, the Federal Wildland Fire Policy fully recognized wildland fire as a critical natural process, while acknowledging the need to reduce hazardous fuels, and promoting agency and intergovernmental cooperation.[14]

Though federal wildland fire policy has evolved to recognize the beneficial ecological role of fire, significant issues remain. Over the years, the Office of Management and Budget (OMB), the Government Accountability Office (GAO), the Congressional Research Service (CRS), DOI's Inspector General, and others have questioned the efficiency and cost effectiveness of both DOI's and the USFS's wildland fire management strategies. Focusing on DOI's fire program, this review identifies the major fiscal, legal, and institutional issues related to wildland fire policies.

Fiscal Issues

Growing wildland fire program budgets have been a concern since at least the 1970s, when OMB and Congress directed the agencies with wildland fire protection responsibilities to become more efficient.[15] Two decades later, with the objective of cost containment, the Strategic Issues Panel on Fire Suppression Costs reviewed over 300 recommendations from five previous years of reports addressing increased fire suppression costs. The panel likened the federal government's approach over the previous two decades to "blank check management."[16] More recently, a 2011 CRS report found that federal wildfire management costs, while fluctuating based on fire season severity in the preceding calendar year, have increased over the past 15 years.[17] Other reports have also identified increasing costs.[18] Budget trends are discussed in more detail in Section 3.

Contributing to the costs has been the notion that there is an "open checkbook" for funding fire suppression, which has also been blamed for creating perverse incentives that unintentionally encouraged federal agencies to focus on wildland fire suppression rather than prevention.[19] There is general agreement in the literature that unlimited emergency suppression funding increased total wildland fire management costs, while creating a disincentive to invest in pre-suppression activities such as prescribed burning, thinning, and post-fire rehabilitation.[20] Keiter states that the results of these fiscal arrangements could be more destructive of forest ecosystems than wildfires.[21]

The FLAME Act of 2009 addressed some of these unintended fiscal consequences, reducing the need to borrow funds from other programs to cover unexpected wildland firefighting costs. The FLAME Act created separate fire suppression accounts, dedicated to covering the costs of suppressing large or complex wildfires, in annual appropriations.[22] CRS reported that while the FLAME Act funds have insulated federal programs from the financial impacts of borrowing from other programs to pay for wildland fire suppression, the FLAME funds do not offer the incentives necessary to reduce or constrain wildland firefighting costs.[23]

Demographic changes in what has become known as the wildland urban interface (WUI) have also contributed to growing costs. The WUI is generally defined as the area where houses meet or intermingle with the undeveloped wildland vegetation.[24] Further discussion of WUI definitions appears in Section 3. Expansion of the WUI has been recognized as an important element of wildfire policy since 1960.[25] GAO analysis indicated that the presence of structures adjacent to federal lands can significantly change fire suppression strategies and increase costs, as fire managers are often required to construct special firebreaks and rely more heavily on aircrafts to drop fire retardant.[26] Focusing federal resources on the WUI has also reduced the resources available for protecting and restoring irreplaceable ecological and cultural resources on public lands outside of the WUI.[27] Critics pointed out that federally funded fuel treatments to protect private WUI property have subsidized private landowners and encouraged continued development in fire-prone areas.[28] Hammer et al. described the WUI as a “wicked problem” nationally, particularly in the West and Southeast.[29]

The GAO noted in 2007 that multiple definitions of the WUI, generated by different policies over the years, had hampered the ability of agencies to appropriately identify and direct funding to the highest priority lands.[30] The 1995 Wildland Fire Policy and its 2001 update recognized the growing fire protection problems in the WUI, and offered cooperative prevention and education, and technical assistance to communities, but left structural fire protection to the tribal, state, and local governments.[31] The federal role and funding in the WUI expanded with the 2003 Healthy Forest Restoration Act, which required that at least 50% of fuel treatment project funding be used in the WUI.[32] CRS estimated that the percentage of DOI’s funding for fuel treatments in the WUI increased 22% in 2001(the first year in which data are available) to 47% in 2008.[33] The focus on WUI fuel treatment funding has continued to increase. DOI budget guidance for 2011 required applying 90% of fuels management funds to the WUI.[34]

DOI’s role in protecting the WUI was recently reassessed. The 2012 Appropriations Act (Public Law 11274) directed DOI “to remove the requirement that ninety percent of hazardous fuels be spent in the Wildland Urban Interface…" Instead, Congress required hazardous fuel funds to be spent, "… on the highest priority projects in the highest priority areas."[35] Related to the WUI issue is the growing federal share of funding for WUI fire protections. The CRS pointed out that while the policy in the 1980's and early 1990's was to cut fire assistance funding for state and volunteer fire organizations, such funding more than tripled in 2001, rising from $27 million to $91 million, due to increased federal funding under the National Fire Plan, and peaked at $314 million in FY 2009, with funding from the American Recovery and Reinvestment Act.[36] Additional discussion of the WUI is found in Section 3.

Another source of wildland firefighting cost increases identified in the literature is the contracting out of wildland fire-related activities. Contracting is generally viewed as a cost effective approach to meet seasonal firefighting requirements, allowing contract firefighters to fill an important niche on an as-needed basis. However, interviews with 48 fire commanders and their staff found that contractors too often did not have the necessary training or experience, resulting in delays in fire suppression and increased costs associated with transporting, recruiting, and training replacement contractors.[37] In a 2010 report, Ingalsbee found that contract crews, who accounted for 56% of large wildland fire suppression costs, required more oversight, which is costly and generally not available.[38] In an analysis of crew costs, Donovan found that given a 14-hour work day and 90 productive days in a fire season, the mean cost of a government fire crew was $2,252 less than that of a contract fire crew. (It was emphasized that this does not imply that government crews are universally cheaper, but are so under certain conditions).[39] In a separate study, Donovan demonstrated that as the number of idle days increases, government crews lose their cost advantage over contracting crews, making the optimal mix of contract and government crews partially dependent on the severity of the fire season.[40] To reduce the transportation component of firefighting costs in Alaska, Congress, as part of the 2012 Appropriations Act, encouraged DOI's Office of Wildland Fire and the Bureau of Land Management (BLM) "to develop a program to train crews in Alaska, particularly the existing native crews that might not now be qualified …"[41]

<u>Legal and Institutional Issues</u>

Federal, state, and local laws and regulations have been blamed for adding to the cost and time required to reduce accumulated hazardous fuels and rehabilitate fire-damaged lands. The 2002 Healthy Forest Restoration Initiative (HRI) and the Healthy Forests Restoration Act (HFRA) of 2003 both sought to streamline required public and environmental review processes in an effort to jump-start fuels reduction and post-fire rehabilitation in and beyond the WUI.[42]

New procedures were designed to enable DOI and USFS to give priority to forest-thinning projects so that they could proceed within one year.[43] HFRA established expedited environmental review and public involvement processes for fuel reduction activities. In addition, DOI and USFS established categorical exclusions from the National Environmental Policy Act (NEPA) for hazardous fuel reduction activities. The HFRA, which was both the first legislation to impose on forest managers a specific statutory duty to reduce hazardous fuels, and the first permanent amendment to NEPA, raised significant opposition.[44] In December 2007, the Ninth Circuit Court of Appeals ruled that the categorical exclusion violated NEPA.[45]

Fire insurance and disaster assistance payments also play a role in wildland fire management. Federal Emergency Management Agency (FEMA) monies, as well as below-market-price private insurance may have the effect of reducing individual responsibility and increasing the demand for federal protection.[46] Bradshaw pointed out that federal disaster assistance has also reduced the incentives for insurance companies to adjust premiums and restrict the availability of coverage to those adopting fire-risk reduction measures.[47] Some assert that the private insurance industry, which is regulated by states, can and should promote fire-sensitive land use and building code reforms by using pricing incentives and risk assessments to encourage homeowners to fireproof their properties and to discourage new construction in the fire prone WUI.[48] Others suggest that states should apply their regulatory authorities to allow insurance companies to charge higher premiums in fire prone areas, and increase public awareness through maps and other means.[49]

States and localities have additional regulatory means of reducing fire hazards. Oregon, Montana, Minnesota, New Mexico, and Washington, for example, require fuel treatments on private land to reduce the probability and severity of wildfires.[50] Localities also have the legal tools to improve wildland fire management. They can use zoning, building codes, firefighting cost agreements, and easements to limit development in high fire-risk areas.[51] Continued federal fire protections in the WUI appear to be making nonfederal governments less likely to invoke their legal authorities, and more reliant on the federal government.[52]

The literature generally viewed disaster assistance payments, below-market insurance rates, and other fire-related assistance to WUI residents as reducing individual responsibility. However, there was no rigorous effort to quantify or estimate the impact of these policies. Kousky and Olmstead noted that:

> Economists have drawn attention to the ability of public policies to induce land development in risky locations through subsidies of various kinds (including subsidized insurance, the construction of infrastructure meant to reduce risk, direct payment for damages in the aftermath of catastrophic events, and other mechanisms), but the literature offers scant empirical evidence to support these claims.[53]

Federal policies have evolved not only to recognize the ecological benefits of fire, but also to give resource managers more flexibility in reducing hazardous fuels and in responding to wildland fires. For example, the "appropriate management response," as used in federal fire policy, now includes a wider range of allowable responses, based on conditions.[54] Peterson wrote that these changes, which allow managers to make decisions based on forest health rather than expedience, are too often more evident on paper than in practice, due in large part to institutional factors.[55] As an example, she pointed out that managers are more likely to be fired for a prescribed fire that escapes and destroys private property than they are for allowing a hazardous fuel buildup that ignites a larger fire that destroys even more private property.

Ingalsbee noted that despite nearly 30 years of ecologically enlightened policies, a lack of incentives and accountability has deterred managers from taking the most cost effective approaches – managers have far more incentive to reduce the potential risk of wildland fire damage, especially to private property, than they do to reduce the costs of wildfire suppression.[56] Others have made similar observations, noting that "individual managers demonstrate higher levels of risk aversion than do agencies, primarily because individual managers are held responsible...."[57] While fire managers are generally not held accountable for excessive spending to control fires, they are blamed for the resulting damages.[58] Too often, fire managers employ expensive firefighting approaches, such as aerial retardant drops, rather than more cost effective ground-based fire suppression techniques.[59] In addressing the link between fire managers' incentives and rising costs, the Strategic Issues Panel on Fire Suppression Costs recommended that the agencies "[c]ommit to improving the fire cost data infrastructure as a prerequisite step towards improving accountability and strengthening fire management performance."[60]

For decades, GAO has analyzed DOI and USFS fire programs and formulated recommendations for making them more cost effective. GAO's long-standing call for the agencies to develop a cohesive wildland fire mitigation strategy to better address the significant barriers to mitigating wildland fire threats was adopted by Congress, and incorporated into the 2009 FLAME Act.[61] In recent testimony, DOI's Inspector General supported GAO's call for a cohesive strategy, but identified significant institutional impediments – interagency and intra-agency differences in planning, budgeting, and funding processes – that have made the goal difficult to attain.[62] Different missions can add even more complications. This is particularly the case for federal versus nonfederal roles and responsibilities.

Yet, despite their different roles and responsibilities, federal, state, tribal, and local governments have a long history of cooperating, first to suppress all fires, and more recently to better integrate their fire programs. In 2011, in response to the FLAME Act requirements, the Wildland Fire Leadership Council, an intergovernmental council of federal, state, tribal, county, local, and municipal government officials convened by the Secretaries of Interior and Agriculture, published the first documents as part of a three-phased approach to develop a National Cohesive Wildland Fire Management Strategy (Cohesive Strategy)[63] and the 2009 Federal Land Assistance, Management and Enhancement Act Report to Congress (Report to Congress).[64] Phase two was completed in 2012 and the third and final phase, which will include a national trade-off analysis, will be completed in 2013.

Section Summary

As seen in Table 2-1, policy changes have been the norm for DOI's wildland fire program. The first major policy shift, from total fire suppression to recognizing fire as a critical natural process, has taken years to implement. Responding to Congress's most recent charge, to shift the emphasis of hazardous fuel reduction funding from the WUI to the highest priority projects and areas, will also likely require time to fully implement. For example, the FY 2012 performance measures, formulated in advance of the WUI policy shift, focus on reducing hazardous fuel in the WUI. It will take time for DOI bureaus to review and modify fire management plans, comply with NEPA, and coordinate with the affected communities and other stakeholders to reflect these and other new policies.

Table 2-1 Major Federal Wildland Fire Policies

Year	Policy	Effect
1911	Weeks Act	The 1910-1935 wildfires inspired a national policy of fire suppression.[65] The Weeks Act enlisted states into a cooperative federal-state effort to extinguish all federal forest fires. In 1922, Congress extended these protections to all public lands and Indian reservations.[66]
1924	Clarke-McNary Act	Tied federal appropriations for cooperative fire assistance to states' adopting full fire suppression policies.[67]
1926	10 Acre Policy	Required the control of all wildfires before they reach 10 acres in size.[68]
1935	10 a.m. Policy	Required suppressing all fires in all locations before 10 o'clock the next morning.[69]
1963	*Leopold Report*[70]	Following the publication of the report, which recognized fire's beneficial role, NPS allowed natural fires to burn if they promoted wildlife/vegetation. USFS dropped the 10 a.m. and 10 acre policies in 1977.[71]
1964	Wilderness Act	Curbed total fire suppression in remote wilderness areas.[72]
1995	Federal Wildland Fire Policy	The Yellowstone fires of 1988 and the South Canyon Colorado fires of 1994 gave rise to calls for a more coordinated approach. This first comprehensive fire management policy covered DOI and USFS. It recognized wildland fire as a critical natural process, acknowledged the need to reduce hazardous fuels, and promoted agency and intergovernmental cooperation.[73]
2001	Federal Wildland Fire Management Policy	Following catastrophic Western fires in 2000, the 1995 Policy was revised to incorporate recommended planning and implementation improvements, which constitute the 2001 policy.[74]
2001	National Fire Plan	The Plan, comprised of recommendations in *Managing the Impact of Wildfires on Communities and the Environment: Report to the President*[75] and FY 2001 Congressional funding requests, expands operational and implementation activities between federal and non-federal entities.[76] Through Congressional direction, a 10-Year Strategy and subsequent Implementation Plan were adopted by federal agencies and Western governors, in collaboration with county commissioners, tribes, and others.[77]

Year	Policy	Effect
2002	Healthy Forest Restoration Initiative	Following a severe 2002 fire season, DOI and USFS proposed administrative changes in NEPA, ESA, and internal appeal processes to expedite hazardous fuel treatments and salvage logging to reduce hazardous fuels accumulation.[78]
2003	Healthy Forests Restoration Act	Authorized hazardous fuel reduction projects on federal lands in designated WUI areas, municipal watersheds, and to protect endangered species. Amended NEPA and Administrative Reform Act to streamline fuel reduction. Requires at least 50% of funding for fuel treatment projects be used in the WUI.[79]
2009	Federal Land Assistance, Management & Enhancement (FLAME) Act	Established separate accounts for funding emergency wildfire suppression activities to reduce transfers from other agency programs. The Act also required DOI and USFS to submit to Congress a cohesive strategy, consistent with GAO recommendations, to address wildland fire problems.[80]
2011	National Cohesive Wildland Fire Management Strategy	The Cohesive Strategy, required by the FLAME Act, provided a framework for a three-phase, collaborative effort that will use a multi-scale approach to assessing fire risk and national tradeoff analysis.[81]

3. DOI Wildland Fire Budget Trends

The GAO, Congress, and others have identified rising costs of federal wildland fire management as an issue of concern. Expenditures on various aspects of wildland fire management have been studied by the USFS, university researchers, CRS examiners, and various nongovernmental organizations. This section discusses the DOI wildland fire management budget, including a review of the relevant literature and a discussion of the factors that influence wildland fire expenditures. In order to account for inflation, all dollar amounts in this section are presented in 2011 (inflation-adjusted) dollars, unless otherwise noted. Also, estimates of obligations (rather than expenditures) are used because of the lag in obtaining final data on the latter.[a]

The DOI Wildland Fire Program budget is managed by the Office of Wildland Fire (OWF). This review will focus on the following major wildland fire appropriation accounts that comprise 95% of total wildland fire appropriations: [82]

1) Preparedness (fire prevention, detection, equipment, training, and baseline personnel),
2) Suppression (wildland firefighting operations),
3) Burned Area Rehabilitation (post fire rehabilitation), and
4) Hazardous Fuel Reduction (treatment to protect lands and resources from wildfire damages).

Other related appropriation accounts include Facilities Construction and Maintenance and Joint Fire Science Program (DOI and USFS interagency research, development, and applications). Rural Fire Assistance (including funds to purchase fire safety equipment, firefighting tools, training, and communications equipment) has also been included in previous years, but is no longer funded. It is important to note that many operational dependencies exist between the major account categories. For example, many suppression and fuel reduction staff and equipment move freely between the two functions. Thus, the precise allocation of funds to these accounts is approximate.

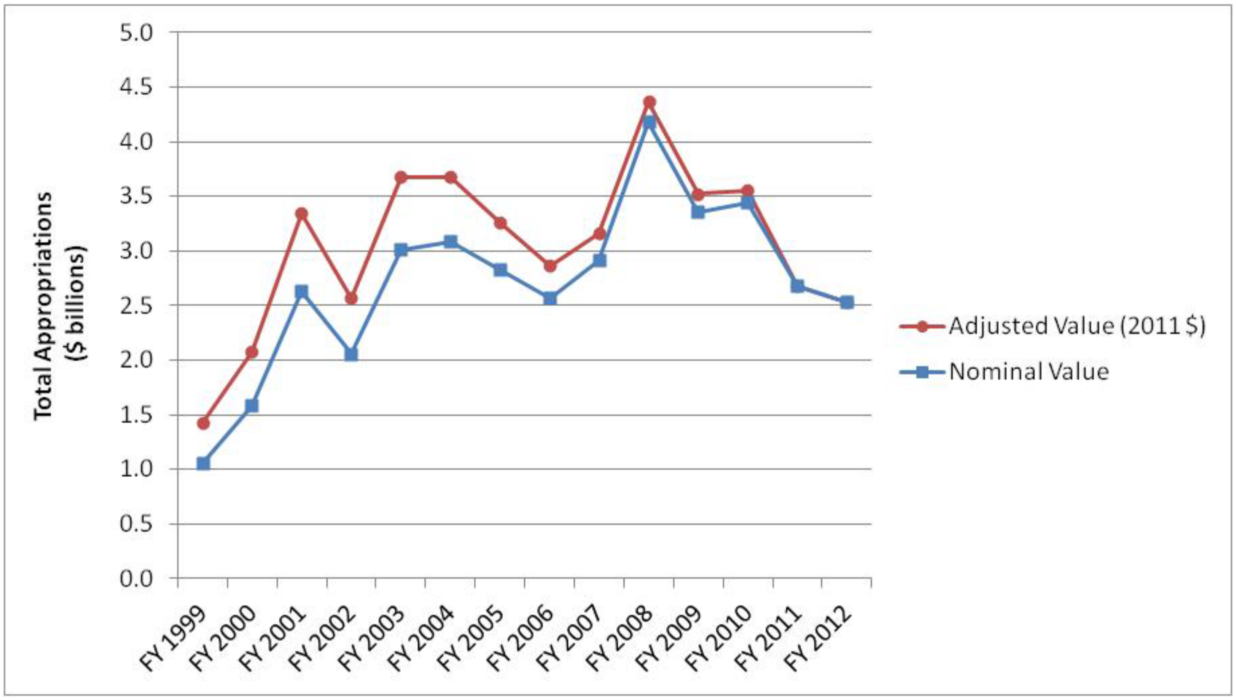
Overview of Federal and DOI Wildland Fire Management Budget Trends

Figure 3-1 shows that federal funding for wildland fire management has fluctuated significantly since the late 1990s. Total federal appropriation levels in FY 2008 were the highest in wildland fire management history, largely due to emergency appropriations to address severe wildland fire activity. Since FY 2008, total appropriations have decreased significantly.[83] In terms of inflation-adjusted 2011 dollars, total federal wildland fire program management appropriations for USFS and DOI were about $1.4 billion in FY 1999, rising to about $4.4 billion in FY 2008, and declining to about $2.5 billion in FY 2012. DOI receives approximately one-third of the

[a] "Obligations" in this section refers to obligations as of November 2011. The information was provided by DOI's Office of Wildland Fire.

total federal wildland fire program appropriations – the other two-thirds going to USFS. Funding fluctuations occur for a variety of reasons, which are discussed later in this section.

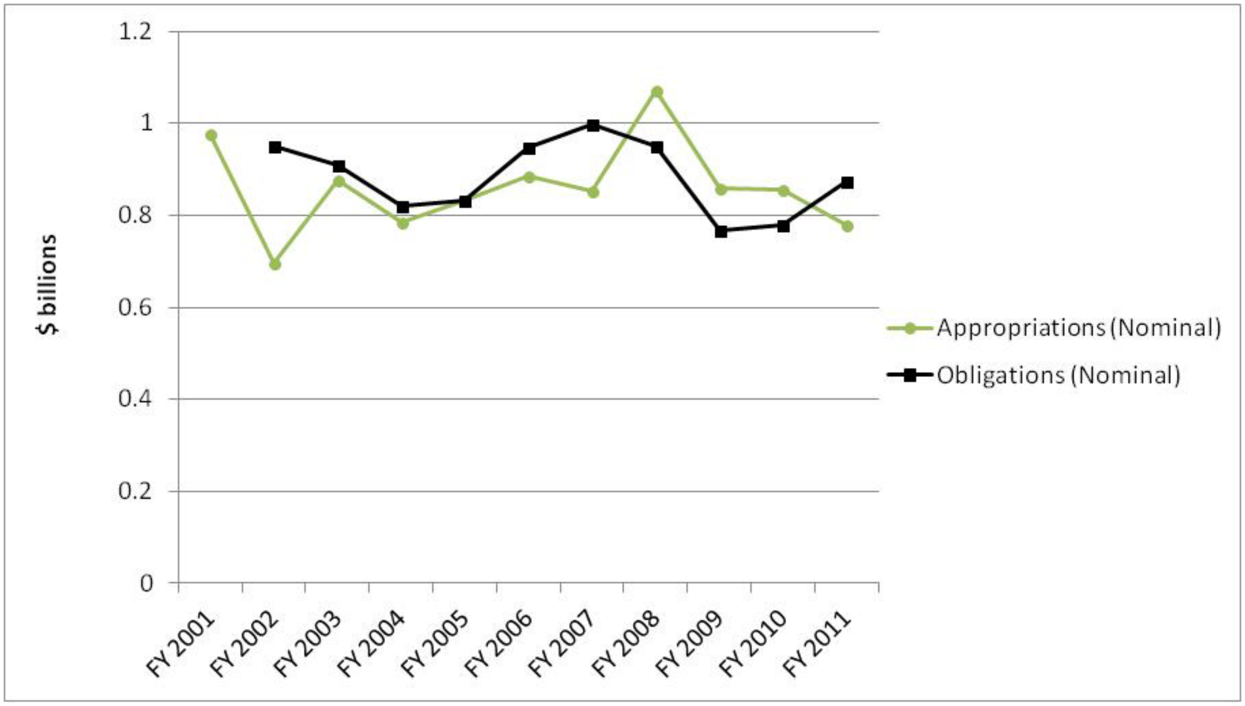
Figure 3-1 Total Federal Wildland Fire Program Appropriations, FY 1999 to FY 2012[1,2]
(Source: Congressional Research Service, 2011)



[1]FY 2012 funding requested in President's Budget
[2]Includes only appropriations for activities on federal lands.

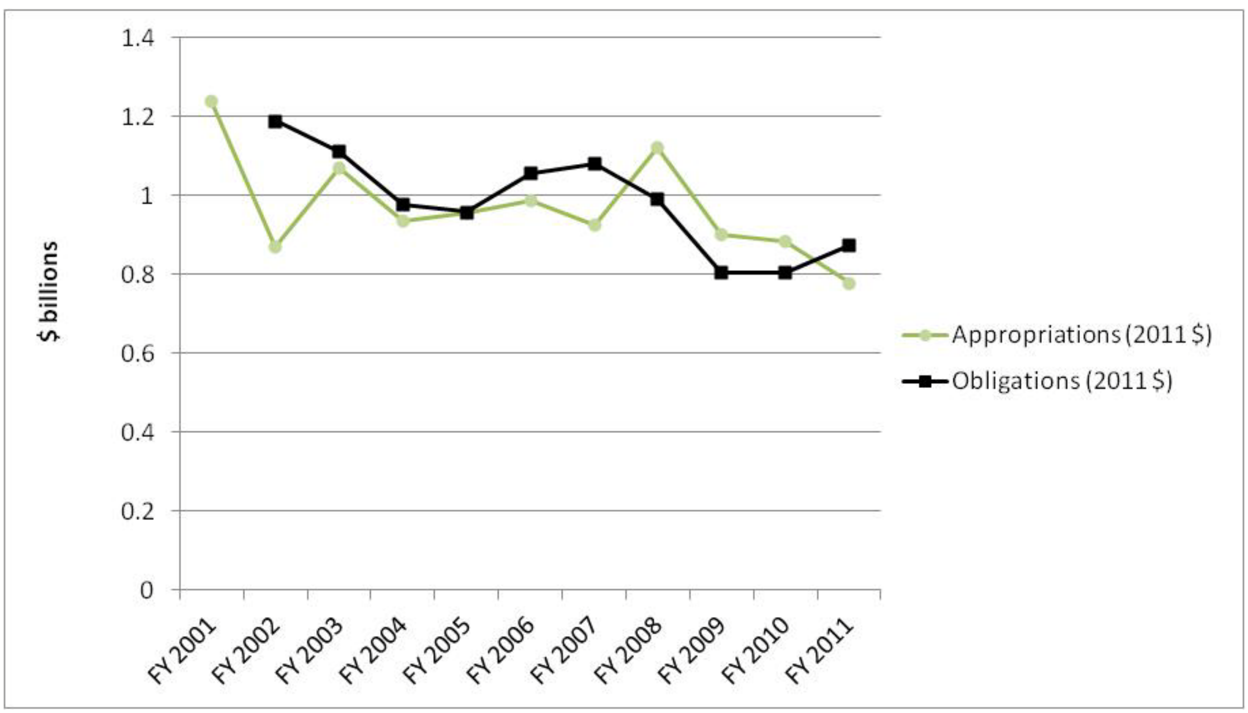
Figure 3-2 shows DOI's Wildland Fire Program appropriations and obligations from FY 2002 through FY 2011, in nominal dollars. Figure 3-3 reports the same series adjusted to 2011 dollars. Annual obligations have fluctuated depending on the extent of wildland fires. During this period, inflation-adjusted appropriations ranged from a high of $1.2 billion in FY 2001 to approximately $800 million by FY 2011. Following the implementation of the 2001 National Fire Plan, there was a slight decline in obligations, from $1.2 billion in FY 2001 to about $870 million in FY 2012. Obligations exceeded appropriations in some years as a result of fund transfers from non-wildland fire accounts to wildland fire accounts in response to active fire seasons.[84] In some years, Congress passed emergency appropriations to cover the transfers.

Figure 3-2 Total DOI Wildland Fire Program Nominal Appropriations & Obligations, FY 2001 to FY 2011[1] (Source: DOI, OWF)



[1] Total program obligation information prior to FY 2002 was not readily available.

Figure 3-3 Total DOI Wildland Fire Program Inflation-Adjusted Appropriations & Obligations, FY 2001 to FY 2011[1] (Source: DOI, OWF)



[1] Total program obligation information prior to FY 2002 was not readily available.

Obligations by Major Wildland Fire Appropriation Account

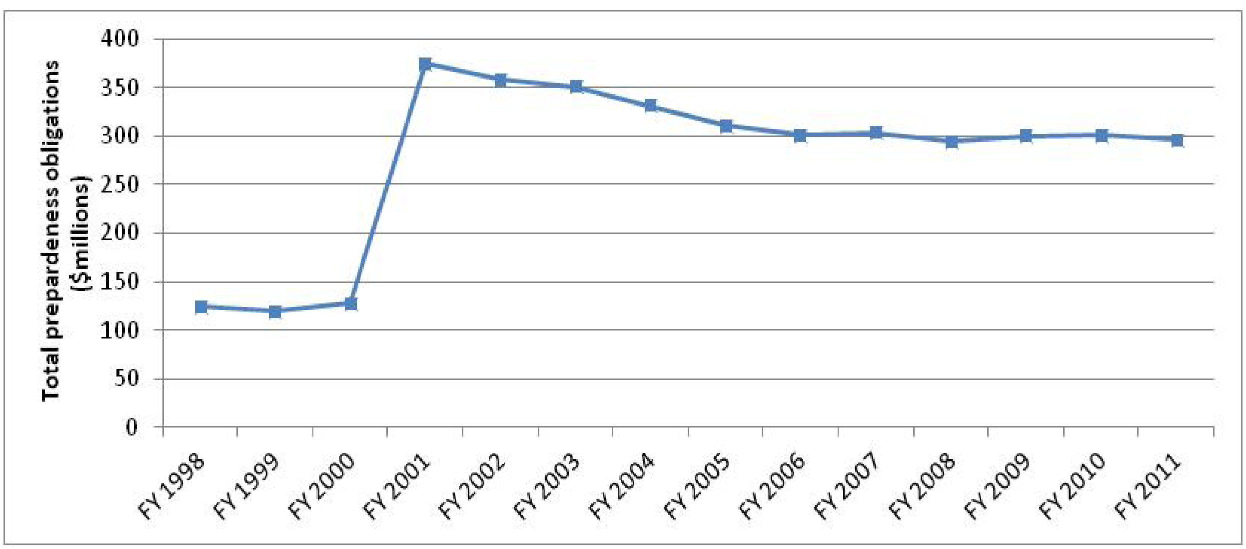
The dollar amounts presented in the remainder of this section are real (inflation-adjusted) 2011 dollars.

Preparedness

Wildland fire preparedness appropriations fund fire prevention, detection, equipment, training, and baseline personnel.[85] Fire management plans provide the basis for wildland fire preparedness staffing, and equipment purchases. Readiness resources to prepare bureaus for the coming fire season are deployed in advance of fire emergencies, based on historical need. Readiness resources include federal firefighter employees, technical personnel who provide leadership, coordination, administration, fire and aviation management, program planning, dispatching, warehouse, and other support functions. Major readiness equipment includes air tankers, retardant bases, lead planes, and large transport plane engines, bulldozers, tractor-plows, and other specialized heavy equipment.[86]

Figure 3-4 shows that DOI's preparedness obligations rose substantially in FY 2001, from $128 million to $377 million, largely as a result of the National Fire Plan, which increased funding to protect federal, state, and private lands.[87] However, since FY 2001, obligations for preparedness, when adjusted to 2011 dollars, decreased through FY 2006, and have leveled out since then to about $300 million per year.

Figure 3-4 DOI Preparedness Obligations, FY 1998 to FY 2011 (2011 $) (Source: DOI, OWF)



Suppression

Suppression appropriations are used to fund wildland firefighting operations. In the past, funds redirected from non wildland fire program accounts were occasionally used to fund expenditures that exceeded the original appropriations. The 2009 FLAME Act established reserve suppression accounts for USFS and DOI, to be funded from annual appropriations. The Secretary is authorized to use FLAME funds when (1) an individual wildfire covers at least 300 acres or threatens lives, property, or resources, or (2) cumulative wildfire suppression and emergency response costs will exceed, within 30 days, appropriations for wildfire suppression and emergency responses.[88]

Figure 3-5 shows that DOI's suppression obligations have fluctuated greatly since 1998, from less than $90 million in FY 1998 to a high of about $500 million in FY 2002 and FY 2007 (2011 dollars). These fluctuations are driven in large part by a variety of factors that are not always predictable. For example, they depend on the weather and climate in specific locales. Emergency appropriations have been approved by Congress after the fire season is nearly complete, resulting in a spike in suppression obligations in years following active wildland fire seasons.[89] This can be seen in Figure 3-9.

Figure 3-5 DOI Suppression Obligations, FY 1998 to FY 2011 (2011 $) (Source: DOI, OWF)

Post Fire Rehabilitation

Burned Area Rehabilitation (BAR) appropriations are used to treat burned resources and maintain proper watershed and landscape function. BAR activities include reseeding to control invasive species, maintaining soil productivity, rehabilitating tribal trust resources, repairing wildlife habitat, and repairing minor facilities damaged by wildfire.[90] Figure 3-6 shows that BAR obligations have generally decreased from a peak of nearly $90 million in FY 2000 to less than $14 million in FY 2011 (2011 dollars).

Figure 3-6 DOI Burned Area Rehabilitation Obligations, FY 1998 to FY 2011 (2011 $)[1]
(Source: DOI, OWF)

[1] Prior to 2004, emergency supplemental obligations were included with burned area rehabilitation obligations.

Hazardous Fuel Reduction

Hazardous fuel reduction appropriations are used to remove or modify wildland fuels to reduce the risk of intense wildland fires, lessen post-fire damage, limit the spread and proliferation of invasive species and diseases, and restore and maintain healthy, diverse ecosystems.[91] Figure 3-7 shows that hazardous fuel reduction obligations peaked in FY 2003, at about $300 million, and has gradually fallen to about $192 million in FY 2011. Much research has been conducted to identify the optimal level of hazardous fuel reduction required to curtail suppression costs. Many researchers and federal managers have argued for greater funding to support fuel reduction treatments, but questions about where to focus treatments remain.[92]

Figure 3-7 DOI Hazardous Fuel Reduction Obligations, FY 1998 to FY 2011 (2011 $)
(Source: DOI, OWF)

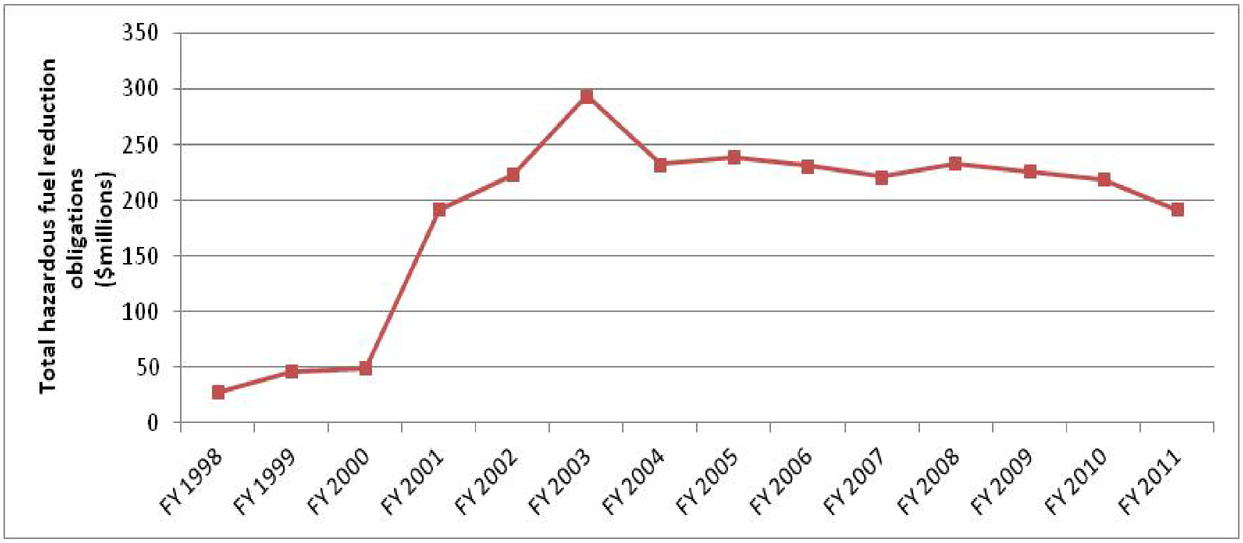
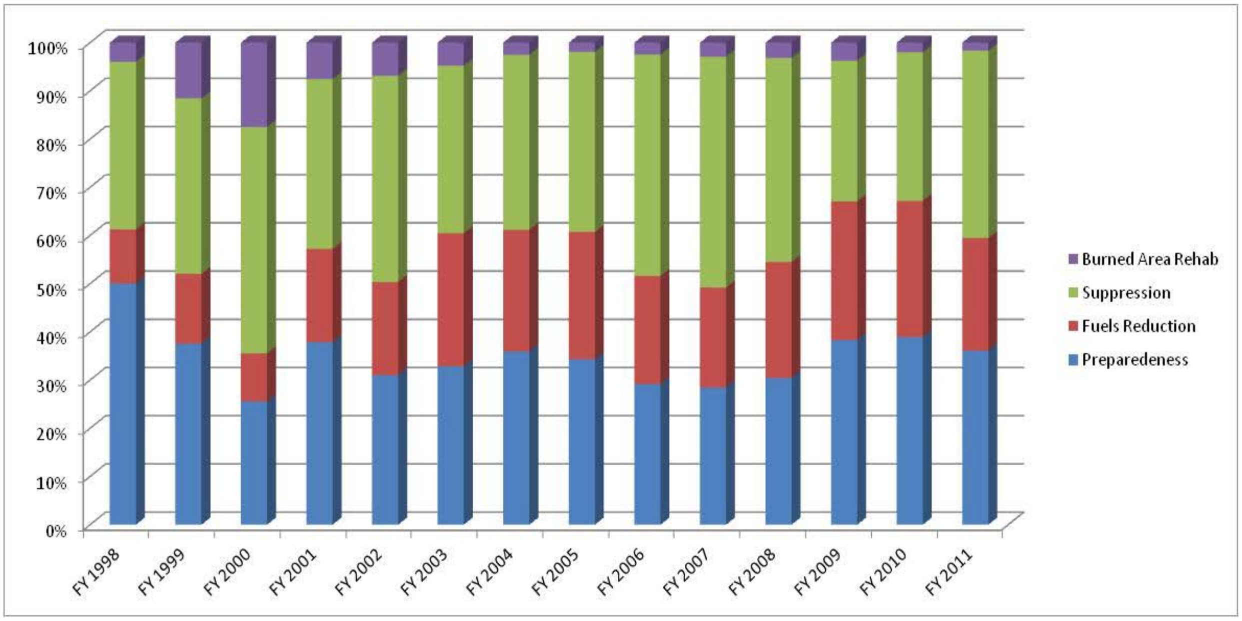


Figure 3-8 shows how DOI's obligations have been apportioned among major wildland fire appropriation accounts – BAR, suppression, hazardous fuels reduction, and preparedness. The figure indicates that suppression represented the largest portion of DOI obligations – 29% to 48% of total obligations since FY 2001. Preparedness, the second largest portion, accounted for 28% to 39% of total obligations since FY 2001. Hazardous fuels reduction is next with 19% to 29% of total obligations since FY 2001. Finally, BAR has represented the smallest portion of DOI obligations – less than 8% of total obligations for all years since FY 2001.

Figure 3-8 Percent of Total DOI Obligations by Account, FY 1998 to FY 2011 (2011 $)
(Source: DOI, OWF)



<u>Factors that Influence Annual Obligations</u>

Annual obligations vary due to a combination of factors, including new policies and congressional actions. The number of acres burned annually, which is at least partly driven by weather and climatological factors, can greatly affect annual suppression costs. Additionally, the expansion of the wildland urban interface has increased the number of lives and properties at risk, and contributed to higher protection costs. The following discussion explores several factors that influence annual wildland fire management program expenditures.

Federal policy

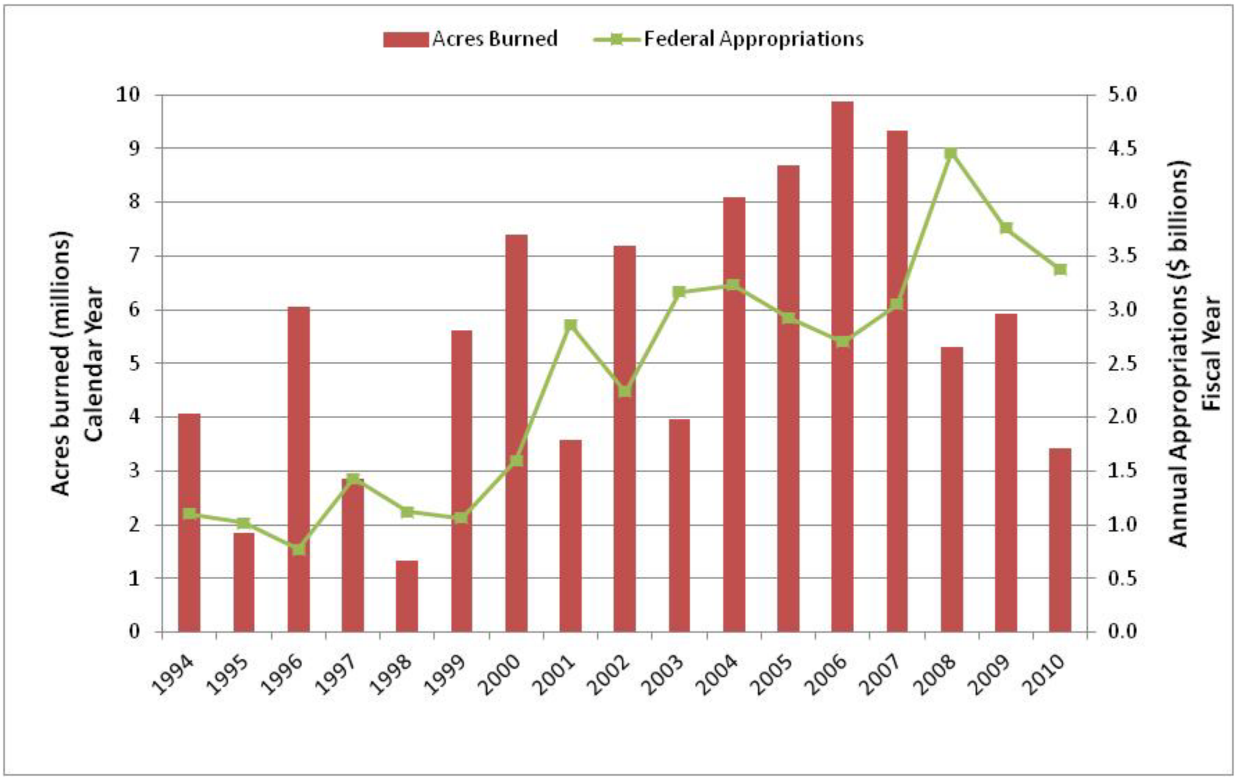
Federal wildland fire management policies can have a significant influence on annual appropriations and obligations. For instance, federal obligations for wildland fire program management increased in FY 2001, in large measure due to implementing the National Fire Plan, which increased funding for certain preparedness, site rehabilitation, and hazardous fuel reduction activities.[93] Total federal obligations for preparedness and hazardous fuel reduction activities increased from approximately $886 million in FY 2000 to over $1.6 billion in FY 2001 (in 2011 dollars). DOI's appropriations for those activities increased from about $177 million to $567 million over this period. DOI Wildland Fire Program obligations increased substantially in FY 2001, to $1.2 billion (2011 dollars), partly due to emergency obligations used to cover costs for the active FY 2000 fire season, but also due to the substantial increase in preparedness and hazardous fuel reduction activities. Obligations for these activities, however, have generally stabilized since FY 2001.[94]

Total acres burned

Fluctuations in annual obligations also depend on the extent of wildfires in a given fire season. The number of wildfire acres burned annually can fluctuate significantly from one year to the next. Over the period from 1994 to 2010, acres burned ranged from a low of approximately 1.3 million acres in 1998, to a high of 9.9 million acres in 2006. Figure 3-9 compares acres burned to annual federal wildland fire appropriations (2011 dollars). Appropriations appear to trend upwards over this period, while acres burned vary widely.

The Strategic Issues Panel on Fire Suppression Costs found that 60% of total suppression obligations can be attributed to the largest 1% of wildland fires.[95] Strauss et al. found that between 80–90% of wildfire acres burned in the Western U.S. are attributable to 1% of wildfires.[96] More research is needed to better capture the relationship between costs and acres burned.

Figure 3-9 Annual Wildfire Acres Burned and Annual Federal Wildland Fire Appropriations, 1994 to 2010 (2011 \$)[1,2,3,4] (Source: DOI, OWF, and CRS)



[1] Fire acre statistics were compiled by states and the National Interagency Coordination Center (by Calendar Year).
[2] 2004 fires and acres do not include state lands for North Carolina.
[3] Annual appropriations were compiled by CRS from agency budget justifications (by Fiscal Year).
[4] In a typical year, October, November, and December represent a relatively small percentage of the total national annual acres burned.

Wildland Urban Interface

The expansion of the wildland urban interface (WUI) is commonly cited as the primary cause of increasing federal wildland fire expenditures and private and public losses.[97] The term *wildland urban interface* has been defined in different ways by different researchers. Stewart et al. point out that the definitions always include a proximity between the presence of human activity and wildland vegetation that represents the potential for impacts beyond the boundary and into nearby lands and neighborhoods.[98] The Western States' Governors' Association and others have described the WUI as containing at least one housing unit per 40 acres. The WUI is composed of both interface and intermix communities. The interface area is at least 50% vegetated. The intermix area is less than 50% vegetated, but within 2.4 km of a large area (>5 km^2) that is more than 75% vegetated.[99]

In 2006, the USDA Office of the Inspector General released a report estimating that 50 to 95% of USFS suppression costs were attributable to the defense of private property, much of which is located in the WUI.[100] It noted that:

> Forest Service's (FS) wildfire suppression costs have exceeded $1 billion in 3 of the past 6 years. FS' escalating cost to fight fires is largely due to its efforts to protect private property in the wildland urban interface (WUI) bordering FS lands. Homeowner reliance on the Federal government to provide wildfire suppression services places an enormous financial burden on FS, as the lead Federal agency providing such services. It also removes incentives for landowners moving into the WUI to take responsibility for their own protection and ensure their homes are constructed and landscaped in ways that reduce wildfire risks. Assigning more financial responsibility to State and local government for WUI wildfire protection is critical because Federal agencies do not have the power to regulate WUI development. Zoning and planning authority rests entirely with State and local governments.[101]

The primary factors in the growth of the WUI include population growth, increase in the number of households, suburbanization, and exurbanization. Data on WUI demographics from the 2010 Census are still being compiled. Information as of 2010 indicated that nearly one-third (32%) of the U.S. population lived in the WUI, and 769,400 km^2 (10%) of all land and 43.7 million (33%) of all housing units in the U.S. were in the WUI, although many of these units are not located in fire-prone areas.[102]

More research is needed to determine the extent to which the WUI affects DOI suppression costs. In addition to suppression costs, the proportion of hazardous fuel reduction funds to the WUI has also increased in recent years. See Section 2, Policy Issues, for more discussion on this topic.

Climate

The role of climate change and ordinary ocean and climate phases in wildland fire activity is frequently raised in the literature. Studies have examined the relationship between climate and fire to better understand how climate fluctuations influence seasonal fire activity. Westerling et al. found that wildfire activity in western forests at the sub-regional level has increased due to warming. Specifically, a transition occurred in the mid-1980s, leading to an increased amount of larger fires with longer duration.[103] Other natural climate variations have been shown to affect wildland fire activity. Collins et al. found that multidecadal climatic oscillations over the Atlantic and Pacific and oceans lead to shifts in climate influence on wildfire extent in the interior west.[104] Kitzberger et al. found that phases of the Atlantic Multidecadal Oscillation (AMO) are correlated with fire synchrony across the western U.S – a positive AMO leads to widespread drought and wildfire events across a large portion of the western U.S.[105]

Several wildfire decision-support models include seasonal climate variations as inputs for allocating resources prior to and during the fire season. Efforts have been made to enhance the use of climate information in models to develop better long-lead suppression forecasts.[106]

Section Summary
Adjusted for inflation, total DOI Wildland Fire Management Program obligations have declined since FY 2002 from about $1.2 billion to $873 million in FY 2011. A sharp increase in appropriations occurred in FY 2001 with the implementation of the National Fire Plan, which substantially increased obligations for preparedness, hazardous fuel reduction, and post-fire rehabilitation activities. However, since the mid-2000s, obligations for these activities have been decreasing, with the exception of suppression obligations, which fluctuate with the amount of acres burned. Some of the most active fire seasons in recent record occurred during the last ten years. This, combined with an expanding wildland urban interface, may be related to increased suppression costs during those fire seasons.

4. Measuring Performance

Introduction
A common thread in the wildland fire literature is that wildland fire management entails a variety of goals and objectives that are not always complementary.[107] The literature also points to varying goals and objectives among the multitude of entities involved in wildland fire management including federal, tribal, state, and local jurisdictions.[108,109] Measuring the effectiveness of DOI's Wildland Fire Program, therefore, involves accounting for differing purposes within and among those responsible for wildland fire programs. This discussion reviews recent agency plans and documents, and selected literature on the goals, strategies, and performance measures for assessing progress and cost effectiveness. Most recent studies addressing performance measure have been written by the federal agencies with firefighting responsibilities and GAO. This section is based on these studies and information from communications with DOI officials.

The Department of the Interior's Performance Metrics
This subsection is informed by the DOI Budget Justifications and Performance Information for Fiscal Year 2012 – Wildland Fire Management.[110] In total, DOI has 16 performance metrics for the fire program in FY 2012. The number of metrics has decreased each year since FY 2008, when there were 26 measures.

For ease of discussion, Table 4-1 links the performance measures (displayed in the second column) to the Wildland Fire Program budget accounts (displayed in the first column). The four budget accounts are described in the budget trends section of this review, and they are:

1) Preparedness (fire prevention, detection, equipment, training, and baseline personnel),
2) Suppression (wildland firefighting operations),
3) Post Fire Rehabilitation (rehabilitation of burned areas), and
4) Fuel Reduction (treatment to protect lands and resources from wildfire damages).

Several performance measures relate to qualitative changes in fire regime conditions, which are classified into three classes based on their relative degree of departure from historical fire regimes. This classification system assists in identifying possible alterations of key ecosystem components, such as species composition, structural stage, stand age, canopy closure, and fuel loadings. In this classification system, the risk of losing key ecosystem components from wildfires increases from Condition Class 1 (lowest risk) to Condition Class 3 (highest risk).[111]

Table 4-1 DOI Wildland Fire Performance Measures by Budget Account. Area is given in acres (ac) (Source: DOI, Wildland Fire Management Budget Justification, FY 2012)

DOI Wildland Fire Budget Account	Performance Measure	FY 2010 Actual	FY 2011 Plan
Preparedness	– Percent of unplanned and unwanted wildland fires on Interior land controlled during initial attack.	98% (5,673/ 5,786 ac)	95% (8,327/ 8,765 ac)
Preparedness/Suppression	– Percent of all fires not contained in initial attack that exceed a stratified cost index.	18%	9%
Suppression	– Percent change from the 10-year average in the number of acres burned by unplanned and unwanted wildland fires in Interior lands.	-41% (-884,429/ 2,178975)	0.2% (3,600/ 2,400,000)
Burned Area Rehabilitation	– Treated burned area that has achieved the desired condition.	1,053,945 ac	1,219,000 ac
	– Percent of treated burned acres that have achieved the desired condition.	95% (1,053,945/ 1,110,844 ac)	99.7% (1,219,000/ 1,223,000 ac)
Hazardous Fuel Reduction	– Percent of acres treated which are moved toward the desired condition class.	75% (961,363/ 1,279,820 ac)	80% (560,000/ 700,000 ac)
	– Percent of acres treated which are maintained in the desired condition class.	18.5% (236,465/ 1,279,820 ac)	14% (100,000/ 700,000 ac)
	– Percent of acres treated which achieve fire management objectives as identified in applicable management plans.	94% (1,197,828/ 1,1279,820 ac)	94% (660,000 700,000 ac)
	– Number of high-priority acres treated in the WUI.	696,523 ac	700,000 ac
	– Area in the fire regimes 1, 2, and 3 moved to a better conditional class (WUI and non-WUI).	WUI 174,347 ac Non-WUI 141,606 ac Total 315,953 ac	WUI 280,000 ac Non-WUI 0 Total 280,000 ac

DOI Wildland Fire Budget Account	Performance Measure	FY 2010 Actual	FY 2011 Plan
	− Area in fire regimes 1, 2, and 3 moved to a better condition class per million dollars of gross investment (WUI and non-WUI).	WUI 174,347 ac Non-WUI 141,606 ac Total 315,953 ac	WUI 1,728 ac Non-WUI 0 ac Total 1,728 ac
	− Area in fire regimes 1, 2, and 3 moved to a better condition class as a percent of total acres treated (WUI and non-WUI). This is also a long-term measure.	WUI 43% of total Non-WUI 57% of total Total 3,084 ac	WUI 40% of total Non-WUI 0% of total Total 40%
	− WUI area treated that is identified in Community Wildfire Protection Plans or other applicable collaboratively developed plans.	594,370 ac	675,000 ac
	− Percent of treated WUI acres that are identified in Community Wildfire Protection Plans or other applicable collaboratively developed plans.	85% (594,370/ 696,523 ac)	96% (675,000/ 700,000 ac)
	− WUI area treated per million dollars gross investment.	696,523 ac $127M =5,479 ac	700,000 ac $162.07M =4,319 ac
Other	− Percent of DOI and USDA acres in good condition (defined as acres in condition class 1) (PART)	TBD	TBD

Performance Issues Raised in the Literature

The need to reduce accumulated vegetation and other fuels to effectively contain wildland fire suppression costs is a common issue discussed in the literature.[112] The literature also notes the lack of effectiveness measures for fuel reduction treatments.[113] Historically, agencies have measured the number of acres treated, which does not necessarily correlate with risk reduction.[114]

Leadership and coordination are commonly discussed issues in the literature. Some studies have reported that improvement in cost effectiveness has been hindered by the lack of strong national leadership rather than the absence of good options and good ideas.[115] Coordination among fire suppression entities has received a great deal of focus, and has motivated agencies to incorporate coordination into their performance elements.[116]

A 2010 study by Calkin et al. examined methods for using available information on several categories of high value resources (as shown in Table 5-5) to measure the effectiveness of wildland fire management programs.[117] The intent was to develop possible performance measures associated with high value resources. The high value resources used by the authors included fire-susceptible species, federal recreation infrastructure, energy infrastructure, air quality, municipal watersheds, fire adapted ecosystems, and built structures. The selection criteria for categories included the availability of data. The authors acknowledge that this is only a partial list of high value resource categories.

The literature identifies climate change as a potentially significant factor with respect to the frequency and severity of wildland fire.[118] Climate change information to inform wildland fire management decisions is currently highly uncertain, particularly at regional and local scales. Nationwide, climate change projections suggest an overall increase in wildland fire severity, with some regions, but not all, experiencing more severe fires.[119] The Future of Wildland Fire Management Report (2009) suggests that performance metrics may need to be reevaluated, based on potential climate change impacts: "It is . . . apparent that new criteria will be incorporated into assessing fire management effectiveness, namely fire severity, landscape restoration, and carbon sequestration."[120]

The literature generally acknowledges the potential inconsistency between the goal of reducing risk to high value resources and the goal of maintaining fire adapted ecosystems.[121] The Cohesive Strategy states, "For many lands, historical fire regimes are not consistent with modern land use objectives."[122] Nevertheless, these two goals persist, requiring land managers to determine the appropriate balance.

According to the GAO, "[t]he agencies have . . . taken steps to address previously identified weaknesses in their management of cost-containment efforts, but they have neither clearly defined their cost-containment goals and objectives nor developed a strategy for achieving them."[123] Subsequent to this GAO study, which was published in 2007, the USFS spearheaded several iterative initiatives: a) Appropriate Management Response; b) Accountable Cost Management; and c) Continuous Improvement in Large Fire Decision Making to address the high cost of costly fires through risk management and cooperator engagement prior to the fire season.[124] A frequently cited concern is that fire incident managers have few incentives to consider cost containment in making critical fire suppression decisions in the heat of battle.[125] For example, while cost containment is recognized as a goal and a metric at the national level, fire incident managers in the field frequently face pressure to devote resources to meet local suppression objectives, which may undercut possible cost saving strategies.

<u>The 2001 Ten-Year Comprehensive Strategy</u>

The Conference Report for the Fiscal Year 2001 Interior and Related Agencies Appropriations Act (Public Law 106-291) directed the DOI and USDA Secretaries to work with governors to develop a ten-year comprehensive strategy for a national wildland fire program. DOI, USDA, and State Governors released the Strategy in 2001,[126] followed by an Implementation Plan in 2002.[127] The Implementation plan was updated in 2006.[128] These documents lay out goals, implementation tasks, implementation outcomes, and performance measures for the wildland fire community. Three guiding principles underlie the Strategy's goals: collaboration, priority setting, and accountability.[129]

The strategy emphasizes a proactive approach to addressing fire on the landscape. It notes that, "It is an effort to move from treating symptoms toward addressing the underlying problems."[130] This is evident in the goals identified in the strategy:[131]

1. Improve fire prevention and suppression,
2. Reduce hazardous fuels,
3. Restore fire-adapted ecosystems, and
4. Promote community assistance.

The 2001 Strategy states that DOI and USDA should develop ". . . common and consistent national performance measures . . ."[132] The performance measures identified in the 2002 Implementation Plan, and subsequently the 2006 update, form the basis for DOI's current performance metrics.

Similar to DOI, the USFS has metrics focused on achieving a desired condition class (DOI and USFS condition classes are the same), fires exceeding a stratified cost index, and treated acres in the WUI. Additionally, the USFS has a metric for the number of acres brought into stewardship contracts.[133]

DOI may adjust the relative importance that it places on the principles from year-to-year, based on its own determination of policy priorities. For example, for Fiscal Year 2012, the primary objectives are to "reduce risks to communities, protect the public and improvements, and to prevent damage to natural and cultural resources through the prevention and suppression of fires." On the other hand, the objectives "[r]educed emphasis… on maintaining or restoring fire adapted ecosystems and managing hazardous fuels for resource benefits in favor of treating lands in the Wildland-Urban Interface."[134]

The National Cohesive Wildland Fire Management Strategy

The Cohesive Strategy establishes a suite of guiding principles including reducing risk to firefighters and the public, emphasizing wildland fire prevention programs, and incorporating wildland fire as an essential ecological process. The three core elements of the Cohesive Strategy are: (1) restoring and maintaining landscapes, (2) achieving fire-adapted communities, and (3) responding to wildland fire. The Cohesive Strategy focuses considerable attention on goals and metrics, and provides overarching goals and performance measures for the wildland fire programs nationally, as displayed in Box 4-1.

Box 4-1 National Goals and Performance Measures, adapted from the National Cohesive Wildland Fire Management Strategy

Restore and Maintain Landscapes

GOAL: Landscapes across all jurisdictions are resilient to fire-related disturbances in accordance with management objectives. [According to the Cohesive Strategy, resilient ecosystems resist damage and recover quickly from disturbances, including such as wildland fires and human activities. (page 33)]

Outcome-based Performance Measure: Risk to landscapes is diminished (centering on risk to ecosystems at landscape scales).

Fire Adapted Communities

GOAL: Human populations and infrastructure can withstand a wildfire without loss of life and property.

Outcome-based Performance Measures:

- Risk of wildfire impacts to communities is diminished.
- Individuals and communities accept and act upon their responsibility to prepare their properties for wildfire.
- Jurisdictions assess level of risk and establish roles and responsibilities for mitigating both the threat and the consequences of wildfire.
- Effectiveness of mitigation activities is monitored, collected, and shared.

Wildfire Response

GOAL: All jurisdictions participate in making and implementing safe, effective, efficient risk-based wildfire management decisions.

Outcome-based Performance Measures:

- Injuries and loss of life to the public and firefighters are diminished.
- Response to shared-jurisdiction wildfire is efficient and effective.
- Pre-fire multi-jurisdictional planning occurs.

A National Cohesive Wildland Fire Management Strategy and companion document (The Federal Land Assistance, Management and Enhancement Act of 2009 Report to Congress) comprised the first phase of a three-phase effort initiated and overseen by the Wildland Fire Leadership Council.[135] Phase II, released June 7, 2012 focuses on restoring and maintaining resilient landscapes, creating fire-adapted communities, and responding to wildfires.[136] Phase III will identify verifiable metrics to measure progress toward achieving the three core elements of the Cohesive Strategy – restoring and maintaining landscapes, achieving fire-adapted communities, and responding to wildland fire – into a national risk trade-off analysis to be completed in 2013.

Performance Measures Used with the Fire Program Analysis Model

The Fire Program Analysis (FPA) system is used by DOI and USFS to make strategic decisions about wildland fire program planning and budget allocations.[137] FPA uses the model and a set of performance measures to compare different possible resource allocations for the coming wildfire season. The performance measures are intended to be used with the model to validate model performance and to provide information for managers at the national level to be utilized in strategic planning. They are not used by agencies to measure or report on past performance. The FPA Desk Guide lists seven performance measures.[138] However, the FPA Analysis Team and FPA Science Team recently undertook an analysis of the performance measures and recommended retaining only the following three objective and quantifiable measures:[139]

1. Suppression costs,
2. Initial response success, and
3. High intensity acres burned.

In 2008 the GAO published a report on FPA, and made several findings relative to performance measures.[140] Although these GAO findings relate to performance measures used with the FPA model for planning purposes, they are also relevant to the performance metrics used for agency reporting to OMB and Congress:

- FPA allows agencies to annually adjust the weight given to different performance measures, thereby increasing the subjectivity of the process, and possibly enabling agencies to use FPA to justify a predetermined outcome.
- FPA considers all acres equally important, despite recognition by agencies that some resources are more essential to protect, such as the WUI and rare habitat types.
- The agencies will need to determine whether the relative importance of performance measures should vary across geographic regions.

One performance measure focuses on protecting highly valued resources, which includes municipal watersheds and habitat for endangered species. According to the GAO, DOI bureaus have concerns about this performance measure because it does not accurately reflect their land management objectives. (It should be noted that the performance measure focusing on highly valued resources is one that the FPA Analysis Team and Science Team recommended be redefined. However, as noted above, it is unclear what constitutes a "highly valued resource." The term "valued" itself suggests a degree of subjectivity in identifying such a resource, the value of which, may vary by location and circumstance.) Currently, FPA is considering only those performance measures which can be objectively measured. The DOI bureaus have not determined how to address highly valued resources. As a result, FPA is not currently using highly valued resources as one of the performance measures in budget scenario analysis.[141]

Section Summary

The number of annual performance measures for DOI's Wildland Fire Program has been reduced in recent years, although they remain generally consistent with those in the 2006 Implementation Plan for the Ten-Year Comprehensive Strategy. The FY 2012 performance measures indicate a focus on hazardous fuel reduction activities in the WUI. Overall, ten performance measures assess hazardous fuel reduction activities, while preparedness, suppression, and post-fire rehabilitation program activities each have two dedicated performance measures. Two FY 2012 performance measures assess cost effectiveness, both measuring hazardous fuel reduction effectiveness per million dollar investment. The literature on performance measures reveals the challenges associated with developing measurable objectives for a program that involves a large number of entities operating at different scales and with a variety of goals that are not always complementary. The many issues raised in the literature indicate that it may be advantageous to examine performance measures in-depth for possible alternatives that would more effectively capture the intent of program goals and objectives.

5. Economic Analysis

Since 1975, agencies with fire protection responsibilities have been called on to improve the economic efficiency of their fire management programs.[142] More recently, the 2012 Appropriations Act directed DOI "to complete an assessment of all Department Wildland Fire programs to determine the most cost effective and efficient means of providing comprehensive fire management services in support of Department and bureau missions."[143]

Economic analyses of fire management over the years have sought to balance the marginal cost of treatment with the marginal benefits to be gained. This approach differs from multi-criteria decision analysis, such as goal programming, as used in Fire Program Analysis, though the optimum identified may turn out to be similar. A central challenge is measuring society's full valuation of resources at risk of fire. Even if values are quantifiable, there is considerable uncertainty as to how potential losses respond to various wildfire management options.[144] An additional challenge lies in balancing the tradeoffs inherent in managing fire-prone forests, as when treatments to reduce fire threat also impact wildlife. This section summarizes the economic literature related to analyzing the benefits and costs of wildland fire programs.

Benefit-Cost Analysis

Benefit-Cost Analysis (BCA) is a technique for evaluating the positive and negative changes associated with proposed policy changes. BCA can serve as an aid for decision making, by identifying and expressing (in constant dollar terms) the net effect of a proposed policy or project.

The effects of a policy change on society are taken to be the aggregate of effects on the individuals who constitute society. Benefits and costs, although typically expressed in dollar terms, go beyond changes in individuals' incomes to include changes in areas such as health or the environment that affect individuals directly or indirectly.

Benefits for marketed outputs may be inferred from the market price of these products. If one effect of a policy will be to extend the life of power infrastructure, this benefit would be calculated using the replacement cost of this equipment, and the additional years until replacement would be necessary. Nonmarket outputs are less straightforward to value. For goods and services that are not bought and sold in markets, it is less clear how to estimate the value of the benefits using willingness to pay. Two major techniques are available. They rely on hypothetical surveys (stated preference methods) or related market data (revealed preference methods).

One common stated-preference approach is contingent valuation (CV). CV involves surveying a sample group to determine what they would be willing to pay for improvements similar to those expected from the proposed policy. One limitation of this approach is that it requires individuals to place dollar values on things that they have little market experience with, and thus are unused to considering in economic terms. Furthermore, these surveys are typically hypothetical, and the values expressed may differ from values that would be revealed in actual market transactions (if actual markets were even available).

More recent developments in nonmarket valuation include attribute-based methods (ABMs) such as conjoint analysis.[145] The objective of an ABM stated preference study is to estimate economic values for an environmental good represented by a set of attributes. This provides a richer description of preferences than can be obtained with CV, where scenarios are described as "with" or "without" the policy change in question. If price is included among the attributes, analysts can develop valuation figures for use in benefit-cost analysis. Survey respondents may be asked to rate or choose among or rank various bundles of goods and services or environmental outcomes. Attributes are traded off in the process of value elicitation, allowing a reduction in one attribute to be compensated by an increase in another attribute. One early environmental application of ABMs was Rae using rankings to value visibility impairments at Mesa Verde and Great Smoky Mountains National Parks.[146] ABMs using rating data to value environmental quality began appearing in the 1990s: Gan and Luzar used ratings to model waterfowl hunting site decisions.[147]

The revealed-preference approach requires observing what people pay for market goods that somehow embody the nonmarket output to be valued. For example, houses in polluted areas typically sell for less than those in unpolluted areas. After accounting for other differences in the houses and areas, the remaining price difference constitutes the premium for a pollution-free home site. A similar approach considers the wage premium required by workers whose jobs pose health risks. Other techniques infer values from such things as the time and money people spend traveling for recreation.

The direct effects of a policy are the expenditures by affected parties, such as firms subject to air-quality regulation. To measure the full social cost, secondary “ripple” effects should also be taken into account, such as increased costs for those who purchase products from a regulated firm, or decreased labor demand by firms that exit the industry. Still, BCA typically relies on changes in direct expenditures as rough measures of true social costs.

Government policies often produce streams of benefits and costs over time rather than all at once. Costs may be incurred early in the life of a project or activity, while benefits may begin to accrue only later. To account for the different values placed on current period changes versus future changes, BCA typically discounts future benefits and costs to present-year dollars. There are technical and ethical issues with discounting. For example, policies with intergenerational effects, such as climate change or disposal of radioactive wastes, involve changes affecting future generations. The high fuel loads currently seen in U.S. forests are a cost imposed by earlier generations on the current generation.

Government policies also affect individuals with a wide distribution of incomes: a billionaire is able—and perhaps willing—to pay more than a pauper for an improvement in environmental quality, though both may care about it with equal intensity. Nevertheless, estimating willingness-to-pay in dollar terms has been found to be a tractable method for measuring the intensity with which people desire something.

Additionally, government policies are subject to political pressures. If a proposed policy is found to have positive net benefits for society, it could still be the case that one group receives most of the benefits, while a second group bears most of the costs. Thus economic efficiency is not the only criterion for evaluating policies.

In spite of the issues raised with BCA, the method supports a systematic approach to decision making, involving listing and considering all the benefits and costs (market and nonmarket) associated with proposed policies. This is an improvement over an approach that allows *ad hoc* or purely political decisions.

<u>*Application to Fire Issues*</u>

Simard argues that at no time in fire management history has the importance of losses and costs been overlooked, citing Pinchot's discussion of wildfire-related human and economic losses, and Greeley's discussion balancing fire risks and property values.[148,149,150] Early modeling of benefits and costs related to wildfire include Sparhawk (1925), Hornby (1936), and Headley (1943).[151,152,153] A survey of these early studies is provided by Gorte and Gorte, who found that early writers developed a least-cost-plus-loss model, positing an optimal level of fire management effort that minimizes the sum of firefighting costs and fire-related damages.[154] The actual choice variable differed by author: Sparhawk used pre-suppression costs, Hornby used acres burned, Arnold (1949) used attack time, and Simard used fire management effort. Sparhawk identified a range of "indirect" resource values, including watersheds, soils, recreation, and wildlife. However, for analysis, Sparhawk tallied only the stumpage value of the timber, citing the "paucity of data" and his estimation that "such damage is less than the probable error in estimating damage to timber."[155] CV has been used to value outdoor recreation resources affected by fire, for example, by Hesseln et al. and Loomis et al.[156,157] Rideout et al. developed an ABM approach for fire management.[158]

The least-cost-plus-loss approach has since been refined in a variety of ways. For example, Donovan and Rideout address a long-standing issue with the "cost plus net value change" (C+NVC) approach, allowing independent levels of pre-suppression and suppression effort, and modeling their dependence via the net cost function (costs minus benefits).[159] Mason et al. consider the specific costs and benefits related to fuel removals for forest fire prevention, as discussed in the following section.[160]

BCA can be performed *ex post*, as a tally of actual net benefits of a project that have accrued up to a given point in time, or *ex ante*, as a planning tool for evaluating project alternatives. This discussion focuses on *ex ante* analysis. BCA is appropriate when benefits and costs of a proposed project can be known, in terms of type, timing, and magnitude. The C+NVC model maps a level of total fire management effort to a total cost: management costs (for suppression and pre-suppression) increase with effort, while net damages (NVC) decline with effort. Tallying the costs is conceptually straightforward, while the benefits (especially nonmarket benefits) are more difficult to quantify.

Cost Effectiveness Analysis (CEA)

A form of BCA known as Cost Effectiveness Analysis (CEA) is one option for including non-use values and other difficult-to-quantify benefits in decision making. CEA was applied to U.S. military expenditures during the 1960s as an approach for "problems in which the output cannot be evaluated in market prices, but where inputs can." CEA seeks to identify the least-cost option for achieving various outputs, such as achieving various levels of a particular management goal. This approach provides decision makers with a menu of potential outcomes (various levels of the management goal in question) and the cost associated with each. Rideout et al. recommend incorporating CEA into the C+NVC approach: quantifiable values are included as part of the NVC, and non-quantifiable values are treated as CEA outputs.[161] This is another approach for combining market and nonmarket values.

Break-Even Analysis

Another approach for situations with well defined costs but benefits that are difficult to measure is break-even analysis. The analyst describes the state of affairs in which the benefits of an action are likely to equal or exceed the (known) costs, and then considers the likelihood of this state coming to pass. Calkin et al. develop the notion of Implied Minimum Value (IMV) as a break-even approach for balancing costs and benefits of fire management.[162] A given level of spending represents a known cost, which is assumed to be justified if it results in expected benefits equaling or exceeding this amount. In particular, the expected benefits are defined as the value multiplied by the reduced likelihood of loss. Dividing the cost of treatment by the reduced likelihood of loss yields the break-even value for resources to be preserved (the IMV). The authors recommend that burned area emergency response (BAER) teams charged with developing economic justifications for their treatment plans use IMV as an alternative to the USFS approach of assigning monetary values to nonmarket resources. Break-even analysis does not avoid the need for nonmarket values, though it does relax the requirement somewhat.

Categories of Costs and Benefits

Hall estimates the total losses due to fire in the United States in 2008 at $362 billion, roughly 2.5% of GDP.[163] Roughly one-third of this ($138 billion) is related to "core costs" as shown in Table 5-1:

Table 5-1 Core Costs of Fire-Related Losses

Property damage	$20 billion
Net insurance premiums (less covered losses)	$15 billion
Professional fire departments	$40 billion
New building fire-protection costs	$63 billion
Sub-total for Core Costs	$138 billion

Another $138 billion of the total is attributed to the value of the time donated by volunteer fire fighters. Human deaths and injuries account for $42 billion, and the balance of $44 billion is attributed to retardants, design safety testing, compliance costs for "fire grade" manufacturing (such as U.L. certification), training and maintenance, standards, and recovery plans.

Hall's tally represents part of what society stands to gain by reducing fire damages; the above categories do not include the various types of "indirect" losses and management costs discussed below. These benefits (in the form of avoided losses) are assumed to be achievable to some degree through investments in fire management.

Dale presents case studies of two Colorado fires, the Hayman and Missionary Ridge fires of 2002, that tally market and nonmarket costs.[164] The market costs include suppression, rehabilitation, and other direct and indirect costs: damages to property, timber, and facilities, evacuation costs, and long-term losses in revenues and property values. The nonmarket costs include impacts to human health and various ecosystem services: values related to aesthetics, wildlife, etc.[165]

Zybach et al. report that USFS suppression costs account for no more than 10% of C+NVC totals.[166] The authors developed a comprehensive ledger intended to allow fire managers to collect comprehensive information about fire costs and damages. In 2011, Oregon State Senator Ted Ferrioli presented a condensed version of this ledger[167] to the Oregon Department of Forestry, requesting that the state adopt a C+NVC reporting methodology that covers:

> "…property damage including the loss of timber and forage, short and long-term health effects, loss of wildlife and habitat, damage to watersheds and water related improvements, carbon emissions, degradation of soils, loss of recreational opportunities, and damage to transportation communication and energy infrastructure."[168]

Zybach et al. discuss three types of cost: *direct costs* include suppression and other expenses related to wildfires that have occurred; *indirect costs* include preparedness measures and reduced aesthetics; *post-fire costs* are long-term losses to society.[169] The "cost-plus-loss" ledger is meant to record these various losses for eleven categories,[b] as shown in Table 5-2.

[b] The descriptions of the categories are non-exclusive, and certain types of losses might be recorded under several categories (e.g., timber, habitat). Some of the included examples are transfer payments, and would not be counted as an economic cost (e.g., taxes). Some of the examples appear unlikely to be related to wildfire (e.g., health insurance as a public health cost).

Table 5-2 Fire Cost Categories (Zybach et al., 2009)[170]

	Category	Direct	Indirect	Post-fire
1.	Suppression costs	wages, transportation, equipment, services, supplies, depreciation, interruption of business, evacuations	preparedness, equipment maintenance	repairs, restocking, medical treatment for responders
2.	Property	structures, communications and transportation networks, timber, and agricultural products	insurance, building/landscape maintenance	repairs, replacement, real estate/sales tax impacts
3.	Public health	injuries, fatalities, hospitalizations, evacuations, medical equipment	health insurance, training	health effects, costs of care
4.	Vegetation	timber, forage, agriculture, habitat	growing stock	future harvests, replanting
5.	Wildlife	habitat	pre-fire population enhancements[c]	restoration, population effects
6.	Water	suppression, system shut-downs	system investments	repairs, impacts on supply
7.	Air and atmospheric effects	pollution, visibility	public health effects, property damage	carbon mitigation
8.	Soil-related effects	erosion	pre-fire investments	erosion, rehabilitation decreased productivity,
9.	Recreation and aesthetics	closures, damaged assets	pre-fire investments	restoration, degraded assets
10.	Energy	grid damage and shut-downs	pre-fire investments, planning costs	repairs, sales reductions
11.	Heritage	cultural/historical sites, supporting businesses	pre-fire investments	repairs, loss of sites

<u>*Facilities*</u>

The value of damage to built structures varies widely within the wildland urban interface over time. Colorado fires in 2002 burned a total of 225,000 acres, and resulted in insurance losses of $70 million. California fires in 2003 burned 750,000 acres, with $2 billion in insurance losses. These two examples alone indicate a range of $72 to $150 in losses per acre.

[c] It is not clear how loss of pre-fire investments differs from the loss of various resources listed under *direct costs*.

Fatalities

In evaluating regulatory effects on health benefits, the U.S. Environmental Protection Agency (EPA) has used a value of $4.8 million for the value of a "statistical life."[171] Mason et al. report an average of 4.8 deaths per million acres of wildland fires over the 1990s. This implies a value of avoided fatalities in the range of $5 to $10 per acre.[172]

Pre-Suppression Costs

Mason et al. describe the costs associated with fuel removal.[173]

- Operational costs of thinning brush and trees,
- Contract costs associated with funding the work,
- Smoke from controlled burns, and
- Environmental impacts of the treatment (habitat losses, soil compacting, damage to standing trees, road sediments), which can be minimized with due care.

Mason et al. also list benefits associated with fuel removal, some of which are associated with the benefits of fewer or less intense fires; other benefits are in fact avoided costs associated with preventing future fires.[174]

Table 5-3 Categories of Benefits and Costs

Benefits of Fuel Reduction	**Benefits of Avoided Fires (Avoided Costs)**	
Community values for fire-risk reduction	Fire-fighting costs	Lost visual amenities
Local economic benefits	Local economic costs (lost tourism, recreation)	Forest regeneration and rehabilitation costs
Biomass energy	Loss of biomass stocks	Habitat losses
Reduced water demand by forests	Increased erosion, sedimentation and water contamination	Smoke
	Fatalities	Loss of carbon stocks
	Damages to facilities	Exotic species invasions
	Timber losses	

Firefighting Costs

Mason et al. report that per-acre firefighting costs decrease with the size of a fire.[175] Data collected for the Fremont National Forest over the 1990s show costs of $8,000 per acre for small fires (less than 10 acres), $3,000 per acre for mid-sized fires (10 to 100 acres), and about $1,100 for large fires (more than 100 acres). Okanogan National Forest data show a similar distribution: about $5,400 per acre for small fires, $3,200 for mid-sized fires, and $500 for large fires.

Federal agencies do not systematically record and track wildland fire data, therefore previous research estimating the economic costs of wildfires has been limited. A few papers have used case studies to determine wildfire losses for specific wildfire incidents. Other studies have used data on insurance losses to estimate wildfire costs. Most of this research is based on case studies as well, although a few studies have produced estimates at a regional or national level.

Table 5-4 shows the results of a 2009 study (updated in 2010) by Dale for the Western Forestry Leadership Coalition (WFLC).[176] The WFLC study places costs and losses into four primary categories: direct costs (including federal, state and local suppression costs, private and public property losses, and aid to evacuated residents), rehabilitation costs (including federal, state and local rehabilitation costs), indirect costs (including lost tax revenue, business revenue losses, property losses that accumulate over time), and additional costs (including human life, physical and mental health needs, ecosystem services). The costs associated with these case studies are not necessarily representative of all larger fires and do not necessarily capture all associated costs and losses. The WLFC study found that the total cost of wildfires (cost plus loss) can range from 2 to 30 times the reported suppression cost.

Table 5-4 Summary Cost Information for Selected Western Fires ($millions) (Source: WFLC Report, April 2010)[177]

Fire Name	Suppression Costs	Other Direct Costs	Rehabilitation Costs	Indirect Costs	Additional Costs	Total Costs	Ratio of Total Cost to Suppression	Suppression as % of Total Cost
Canyon Ferry Complex (MT 2000)	$9.5	$0.4	$8.1	$0.1	n/a	$18.1	1.9	53%
Cerro Grande (NM 2000)	$33.5	$864.5	$72.4	n/a	n/a	$970.4	29	3%
Hayman (CO 2002)	$42.3	$93.3	$39.9	$2.7	$29.5	$207.7	4.9	20%
Missionary Ridge (CO 2002)	$37.7	$52.6	$8.6	$50.5	$3.4	$152.8	4.1	25%
Rodeo-Chedeski (AZ 2002)	$46.5	$122.5	$139.0	$0.4	n/a	$308.4	6.6	15%
Old, Grand Prix, Padua (CA 2003)	$61.3	n/a	$534.6	$681.0	n/a	$1,276.9	20.8	5%

Yale University's Global Institute of Sustainable Forestry conducted a similar study that assessed costs and losses resulting from 10 selected wildfires, four of which were also assessed in the WFLC study (Canyon Ferry Complex, CO; Cerro Grande, NM; Hayman, CO; and Rodeo-Chediski, AZ).[178] The study found that wildfire damages to structures and private property resulted in the greatest losses, followed by damages to timber resources. The study also found that, while the overwhelming majority of wildfire impacts are negative, positive impacts can result from wildfires, such as improved habitat for certain species and short-term economic impacts from wildfire suppression activities.

Some studies have used information on insurance losses to show broader national-level trends. A World Wildlife Fund and the Allianz Group study shows that catastrophic wildfire insurance losses from 1970 to 2004 totaled about $6.5 billion.[179] A report by Grossi estimated that insured wildfire losses from 1961 to 2007 totaled over $11 billion. Catastrophic wildfires for this study had insured losses greater than $25 million.[180]

A majority of catastrophic wildfires occur in California, due to large populations in the wildland urban interface and California's climate and vegetation conditions, which are favorable for wildfires. Information gathered by the Insurance Information Institute shows that 10 of the costliest wildfires in U.S. history have occurred in California.[181] In 2008, the California Department of Forestry and Fire Protection reported that over $105 billion of property was located in high-risk wildfire areas. From 1997 through 2007, wildfire insurance losses in California averaged approximately $490 million annually.[182]

Usefulness, Relevance, and Applicability

As early as Sparhawk (1925), analysts have understood that fire management consists of various stages, with different costs for each stage.[183] Rideout and Ziesler find that costs related to at least two phases of suppression (*initial attack* and *extended attack*) must be considered separately.[184] Scott develops a method for identifying efficient fuel treatment (pre-suppression) decisions, considering the benefits and costs in terms of changes in fire probability, fire behavior, and resulting damages.[185] It is unclear how this approach accounts for the effects of pre-suppression activities on suppression costs. Given the interrelated nature of pre-suppression and suppression, the optimal level of effort in any one stage appears to depend on the optimal level of effort in all other stages as well.

Rideout and Ziesler discuss three "myths" pervasive in wildland fire management, and stemming from the C+NVC model.[186] The three myths (and clarifications) are:

- *Myth: Fuels treatment reduces optimal* ***suppression*** *and/or the optimal level of* ***damages*** *(NVC).*
  Clarification: Based on the model, fuels treatment reduces the optimal level of **total costs** (C+NVC).
- *Myth: Minimizing C+NVC yields the optimal level of effort.*
  Clarification: The optimal level of effort consists of minimizing C+NVC simultaneously for both initial attack and extended attack.
- *Myth: Higher initial attack success is preferred to lower initial attack success.*
  Clarification: For a given set of fires, there is an optimal level of initial attack spending. Some fires are better managed with extended attack.

Scott summarizes the quandary of the decision maker: when scarce capital is the only limiting factor, economic optimality requires first implementing the projects with the highest benefit-cost ratio, until the available capital is expended.[187] In reality, operational or political constraints may require the decision maker to adopt an economically sub-optimal solution, and a BCA would be only one of several factors influencing the decision, particularly given the limitations in our ability to place values on all outcomes. Projects where costs outweigh benefits cannot be justified based on a BCA alone; project funds could instead be invested and used to compensate for the costs. Alternatively, there may be additional benefits that were not included in the quantitative portion of the analysis.

Application to Fire Issues

Fire risk/hazard analysis has been performed at the level of the watershed and the National Forest.[188] Linking probabilities of fire and fire intensity to national benefit/loss functions requires a larger amount of data and consideration of a potentially wider range of ecological and human interactions. A first-order approximation of expected losses and benefits concentrates on so-called "highly valued resources" (HVR).

The national approach taken by Calkin et al. requires simulating wildfires to generate burn probabilities (using FSim or similar models), identifying HVR across the landscape, and developing response functions for the impact of fire on HVR.[189] Categories of HVR included in an analysis may vary; Calkin et al. chose seven categories based on available and nationally consistent data:

- Energy infrastructure,
- Recreation infrastructure,
- Critical habitat for fire-susceptible species,
- Air quality,
- Municipal watersheds,
- Fire-adapted Ecosystems, and
- Residential structures.

Each of these seven categories may contain one or more resources for potential analysis (see Table 5-5). Calkin et al. matched each resource of interest to a stylized response function based on how fires of different intensity might affect the resource.[190] For example, power transmission structures are assumed to be resilient to low- or medium-intensity fires, while high-intensity fires can cause substantial negative impacts. In contrast, ski areas may provide increased benefits following low-intensity fires (effectively accomplishing desirable vegetation management, and preventing more intense, future fires), while medium- or high-intensity fires will reduce benefits proportionally.

Data Sources

One difficulty in choosing data is the requirement for consistency across a range of locations, as determined by the scale of the analysis. The level of detail available in datasets is also important, and the analysis should ideally be able to differentiate between relatively high-valued or scarce resources and lower-valued or abundant resources. For example, recreation infrastructure data may not differentiate between primitive and developed campsites.

Table 5-5 Highly Valued Resources by Category, Including Data Sources (Source: Calkin *et al.*, 2010)[191]

HVR Category	Specific Resource	Data Source
	Power Transmission Lines	Homeland Security Infrastructure Program FSGeodata Clearinghouse Cartographic Feature Files (CFF) (http://svinetfc4.fs.fed.us/clearinghouse/index.html)
Energy Infrastructure	Oil and Gas Pipelines Power Plant Locations	National Pipeline Mapping System Homeland Security Infrastructure Program
	Cellular Tower Point Locations	Federal Communication Commission http://wireless.fcc.gov/geographic/index.htm
Federal Recreation and Recreation Infrastructure	USFS Campgrounds	USFS, FSGeodata Clearinghouse-Vector Data Gateway http://svinetfc4.fs.fed.us/vectorgateway/index.html
	Ranger Stations	ESRI Data and Maps 9.3
	BLM Recreation Sites and Camp-grounds	GeoCommunicator http://www.geocommunicator.gov/GeoComm/index.shtm
	NPS Visitor Services and Camp-grounds	National Park Service (NPS) Data Store http://www.nps.gov/gis/data_info
	FWS Recreation Assets	USDI Fish and Wildlife Service (FWS)
	National Scenic and Historic Trails	NPS Data Store http://www.nps.gov/gis/data_info
	National Alpine Ski Area Locations	National Operational Hydrologic Remote Sensing Center http://www.nohrsc.noaa.gov/gisdatasets/
Fire-Susceptible Species	Designated Critical Habitat	U.S. Fish and Wildlife Service Critical Habitat Portal http://crithab.fws.gov/
	National Sage-Grouse Key Habitat	Bureau of Land Management (BLM)
Air Quality	Class I Airsheds	NPS Air Resources Division http://www.nature.nps.gov/air/maps/receptors/index.cfm
	Non-Attainment Areas for PM 2.5 and Ozone	Environmental Protection Agency downloaded from www.myfirecommunity.net
Municipal Watersheds	Sixth Order Hydrologic Unit Codes	Natural Resource Conservation Service
Fire-Adapted Ecosystems	Fire-Adapted Regimes	LANDFIRE map products http://www.landfire.gov/
Residential Structure Location	Pixels Identified as Containing Built Structures	LandScan USA

Usefulness, Relevance, and Applicability

There are several challenges to tallying values from multiple sources:

- Researchers' understanding of how nonmarket values are affected by fire,
- Lack of willingness-to-pay data for nonmarket value conservation,
- Violations of the individual's budget constraint,
- Infeasibility of valuing (particularly indigenous) cultural heritage, and
- Necessarily *ad hoc* weights applied to diverse risk and value categories.

Tradeoffs in Fire Management

Adding to the difficulty of valuing nonmarket goods is the fact that actions in support of one management goal may undermine efforts in support of a different goal. Hummel et al. present an example of managing both to reduce fire threats and preserve forest habitat for the northern spotted owl.[192] Production possibility curves trace out the tradeoffs between these two goals in terms of relative cost: depending on the current and desired levels of these two goals, a lower fire threat may require reduced owl habitat. Calkin et al. note that a production possibility analysis describes the result of a chosen alternative as an opportunity cost.[193] For a matched pair of resources subject to this sort of tradeoff, if only one resource has a well defined market value, the tradeoff can be used to develop an implied value for the other (nonmarket) resource.

In yet another approach, Venn and Calkin propose an approach relying on deviations from the historical range and variability (HRV) for fire regimes and for wildlife and vegetation (including type, composition and community structure).[194] USDA and DOI defined HRV as: "natural fluctuation of ecological and physical processes and functions that would have occurred during a specified period of time" (in particular, prior to settlement by Euroamericans in the mid 1800s).[195] Measures of departure from HRV could be used as a proxy for changes in social values arising from wildfire management options. HRV might be applied to the tradeoff approach described above, allowing HRV to represent all nonmarket resources as one side of the production possibility curve.

Section Summary

A fundamental question connected with expenditures of public funds is whether the end product is "worth it" for the public. Wildfire management is no exception. Attempts to justify the large expenditures related to avoiding and suppressing wildfire typically focus on identifying direct expenditures and avoided costs, are defined as economic benefits. In the context of economic analysis, this is an incomplete description of social costs, which would ideally include values for all resources at their opportunity cost. One of the greatest challenges with comparing costs and benefits is in characterizing everything in terms of a common metric, such as dollars, especially as nonmarket goods and services often are difficult to quantify and monetize. Decision makers may never have comprehensive, succinct ledger entries to show the economic value of protecting resources like human health, cultural sites, and wildlife habitat. Approaches like benefit-cost analysis, cost effectiveness analysis, and focusing on highly valued resources inform decision makers about the tradeoffs they face.

6. Wildland Fire Models

Introduction

Just as fire policy has evolved, so have the tools for planning, budgeting, and managing fires.[196] This section provides a brief summary of a sampling of the various models used in different aspects of fire management.

With the rapid progress in computer technology came the ability to use large datasets to better simulate and project wildland fire behavior at finer resolutions and shorter time steps. In parallel to these activities, a number of fire effects models were developed, which then were coupled with the behavior models and with models containing information on various costs and benefits associated with measures to prevent or suppress fires to form decision support systems. This has also resulted in a wide range of models tailored for specific management needs and uses.

This review will provide a brief background and overview of several primary models used for modeling fire behavior, fire effects, and decision support systems. It is important to note that many of these models are not independent. They often contain common elements and are frequently used in conjunction with each other and other systems and databases. Sometimes, such as in the case of LANDFIRE, new systems are created to meet the needs of pre-existing models, or biophysical models which are not fire based are extended to include wildland fire components.

Table 6-1 highlights commonly used models and their capabilities. It is not intended to be a comprehensive look at all available fire models or the theories behind them. Currently, hundreds of models and tools are available for use for various aspects of wildland fire management. A more complete discussion of the available models and tools, and the wildland fire management community's plans to deal with this situation was prepared by the Joint Fire Science Program.[197]

Fire Behavior Models

Much of the development of fire models is based on the efforts of researchers with the USFS. In his 1972 paper, "A mathematical model for predicting fire spread in wildland fuels," Richard Rothermel developed a set of mathematical equations to model surface fire spread.[198] These models were then adapted by Frank Albini into a set of nomograms – graphical aids or charts – to help facilitate computing fire behavior and characteristics for a combination of variables (such as wind speed, terrain slope and fuel moisture) using fuel models suitable for the area of interest.[199] Such nomographs were employed frequently by engineers to solve complex calculations before computers were widespread, portable, cheap, and easy to use. In 1976, at the recommendation of Rothermel, Andrews started developing BEHAVE, a computer program designed to automate these nomograms.

This has evolved into BEHAVEplus, a group of models that simulate fire behavior, fire effects, and the fire environment.[200]

Starting in 1998, NEXUS, a spreadsheet, was developed to link surface and crown fire prediction models. It has been used to evaluate alternative treatments for reducing crown fire risk and assessing the potential for crown fire activity.[201] Originally funded by the USFS and the NPS, Dr. Mark Finney initiated the development of FARSITE, a fire growth simulation modeling system, in 1993. It uses spatial information on topography and fuels along with weather and wind files. It incorporates models for surface fire, crown fire, spotting, post-frontal combustion, and fire acceleration into a 2-dimensional fire growth model.[202,203] FARSITE's initial purpose was to produce stand-alone fire growth simulations using all operational fire behavior models, including models for surface fire, crown fire, spotting, fuel moisture, fire acceleration, and fuel consumption.[204] It has since evolved beyond that role into a tool used by many land management agencies to aid in broader fire suppression and management decisions.[205]

Fire Effects Models

By contrast to the fire behavior models described above, fire effects models are designed to estimate the effects of fire. These models evolved from vegetation succession models that were developed in the 1970s.[206] One of the earliest models was the First Order Fire Effects Model (FOFEM), developed in 1989 by the USFS and the Joint Fire Science Program. FOFEM is designed to project the short-term biophysical impact of fires, providing quantitative information on tree mortality, fuel consumption, mineral soil exposure, smoke, and soil heating.[207] Its other anticipated uses include: setting acceptable upper and lower fuel moistures for conducting prescribed burns; determining the number of acres that may be burned on a given day without exceeding particulate emission limits; developing timber salvage guidelines following wildfire; and comparing expected outcomes of alternative actions. Development of FOFEM is ongoing.

Fulfilling a similar function as FOFEM, but for longer time scales, is the Forest Vegetation Simulator-Fire and Fuels Extension (FVS-FFE). This consists of the Forest Vegetation Simulator, first developed in 1973, to model natural succession and vegetation dynamics for northern Idaho and western Montana, linked to a forest and fuels module which models snag (i.e., dead or dying trees), fuels, and fire behavior. In simulating fuel dynamics, processes such as litterfall, snag fall down, the accumulation of activity fuels, and decomposition are modeled. Fuel loading, forest type, and other stand characteristics, are used to classify stands into one of the standard fuel models used to model fire behavior. Fire behavior is then represented using existing methods, e.g., the algorithms used in BEHAVE and NEXUS are used internally to estimate surface and crown fire behavior. Fire effects equations were also taken mostly from published work. FFE has been developed for almost all of the twenty FVS geographic variants.[208,209]

Various models were developed in the early 1990s to capture different biophysical effects of wildland fires. Many of these models are also ongoing projects. These models, some of which could be viewed as precursors to decision support systems, include FireFamily Plus, a software for analyzing and summarizing historical weather observations and computing fire danger indices of the National Fire Danger Rating System (NFDRS). Fire occurrence data can also be analyzed and cross referenced with weather data to help determine critical levels for staffing and fire danger.[210,211]

Another model is the Fire Effects Tradeoff Model (FETM), which is designed to simulate the tradeoffs between alternative land management practices over long periods of time (up to 300 years) and under diverse environmental conditions, natural fire regimes, and fuel and fire management strategies. FETM is essentially a vegetation dynamics model that simulates changes in vegetation composition over time in response to various human-caused and natural disturbances (e.g., timber harvest, mechanical fuel treatments, prescribed fire, wildland fire, wind throw, insects, disease, as well as natural succession). The predicted changes in landscape composition are used to calculate, among other things, smoke-constituent emissions from prescribed fire and wildland fire events, costs and benefits associated with wildland fire and fuel treatment, and the number (but not the location) of treated acres annually.[212]

Yet another is FlamMap, a mapping and analysis tool, initially designed in 2000 to model fire characteristics based on existing environmental conditions.[213] FlamMap was designed to be used in conjunction with BEHAVEplus, FARSITE, and FSPro as part of a suite of wildland fire modeling tools for land and resource managers. These are complementary systems that are based on essentially the same fire models.

In 2001 the LANDFIRE prototype project was developed by the USFS and DOI to provide the "baseline data needed to implement the National Fire Plan."[214] LANDFIRE provides fuel characteristics and vegetation layers which other fire models (e.g., BEHAVEplus, FARSITE, FOFEM, and NEXUS) and funding allocation processes, such as the DOI Hazardous Fuels Prioritization and Allocation System (HFPAS), now utilize as inputs.

Decision Support Systems

A 1978 mandate by Congress, requiring USFS to conduct a benefit-cost analysis of its fire management program, led to the development of the National Fire Management Analysis System (NFMAS), one of the first decision support systems. This evolved into a tool for managers to evaluate alternative fire management programs against such things as land management objectives, program budget level, and dispatch strategies in order to allow field units to estimate the economic efficiency of proposed program alternatives.[215,216] Also, in the late 1970s, the Escaped Fire Situation Analysis (EFSA) was developed by the USFS to establish suppression alternatives for uncontrolled fires. The EFSA evolved into Wildland Fire Situation Analysis (WFSA) and was computerized in the late 1990s.

The USFS, BLM, and BIA employed the economic values from NFMAS for use in WFSA. However, in deference with the philosophy that many NPS resources and values were non-market and difficult to quantify in dollars, the NPS and USFWS did not use the NFMAS values. Instead, they developed and adopted an alternative system, FIREPRO, in 1983, which used a non-monetized rating system in lieu of absolute dollars. The FWS would adapt that into a system called FIREBASE in the early 1990s.

WFSA was deemed to be too cumbersome, and the National Fire and Aviation Executive Board chartered the Wildland Fire Decision Support System (WFDSS) to replace it by 2009.[217] The WFDSS became operational in 2007.[218] It is a suite of models using LandFire, fire spread probability mapping (FSPro), economic valuation of values at risk within the potential area of spread (RAVAR), and a stratified cost index program (SCI) for tracking fire management costs in relation to similar fires.[219] All of this information is displayed using Google Earth as the geospatial backbone. It assists fire managers and analysts in making strategic and tactical decisions for fire incidents, and provides an easy way to document the decision making process for all types of wildland fire.[220] WFDSS is more for post ignition response, whereas most of the other models discussed here are for pre-planning/upfront planning for various aspects of the overall wildland fire management program.

Another system that can be used to assist in decision making is the Wildland Fire Assessment Tool (WFAT), which is designed to help:

- Define and identify the location of hazardous fuel,
- Prioritize, design, and evaluate fuel treatment projects,
- Develop burn plans for prescribed fire,
- Predict fire behavior and effects for summary in planning and monitoring documents, and
- Calibrate fuel data layers based upon observed fire behavior.

It uses FlamMap3 and First Order Fire Effects Model (FOFEM) algorithms to produce fire behavior and fire effects map layers, and can be used to create additional predicted fire effects map layers.[221]

In the meantime, there was a growing recognition that none of the agencies adequately quantified the full range of fire management goals and program activities necessary to identify and improve program efficiencies in a single coordinated planning platform.[222] Accordingly, in 2001, Congress directed the USDA and DOI to implement a common system.

In 2002, an interagency tool, the Fire Program Analysis (FPA), which succeeded NFMAS and several other planning tools in use, was initiated to provide managers with tools to analyze tradeoffs for strategic planning and budgeting to support comprehensive, interagency fire management programs.[223] FPA was tasked to evaluate the effectiveness of fire management strategies for meeting fire and land management goals. Model effectiveness was to be judged based on the following performance metrics:

- Reducing the probability of costly fires,
- Reducing the probability of costly fires within the WUI,
- Increasing the proportion of land meeting or trending toward attaining fire and fuels management objectives,

- Protecting highly valued resource (HVR) areas from unwanted fire,
- Maintaining a high initial attack success rate,
- Decreasing the proportion of land burning above the damaging threshold, and
- Increasing the proportion of land burning at or below the damaging threshold.

FPA has also been used in an analysis of performance measures (as described in the Chapter 4). FPA's Fire Planning Units (FPUs) are used by a number of other modeling efforts as the common inter-jurisdictional assemblages nationally. FPA uses the corporate fire occurrence data set, LandFire, and the Fire SIMulation system (FSIM). (FSIM is incorporated into the Large Fire Module to estimate the burn probability and variability in fire behavior across large landscapes. These are, in theory, combined with information on a variety of HVRs and associated response functions to calculate changes in the net resource values resulting from fire (characterized by "net value changes," NVCs).[224] In practice, though, there are severe limitations in the ability to obtain agreement on the comprehensive information on HVRs and response functions. This limitation is compounded by the fact that it is difficult to compare one type of resource, and changes in its value, with another.[225]

A separate system, the Hazardous Fuels Priority Allocation System (HFPAS), is used to allocate funds appropriated for hazardous fuels reduction (HFR) to projects that have the highest priority in DOI-managed areas where wildfire has the highest potential for negative consequences for both human beings and ecosystems, regardless of which bureaus may be responsible for managing the land where the projects might be located. Accordingly, HFPAS is based on a joint assessment of all DOI lands, as opposed to a bureau-specific analysis. It utilizes a number of tools including the Ecosystem Management Decision Support (EMDS) model and the Project Priority System (PPS).

The approach that EMDS employs currently was first undertaken for the FY 2011 budget exercise. It is illustrated in Figure 6-1.[226]

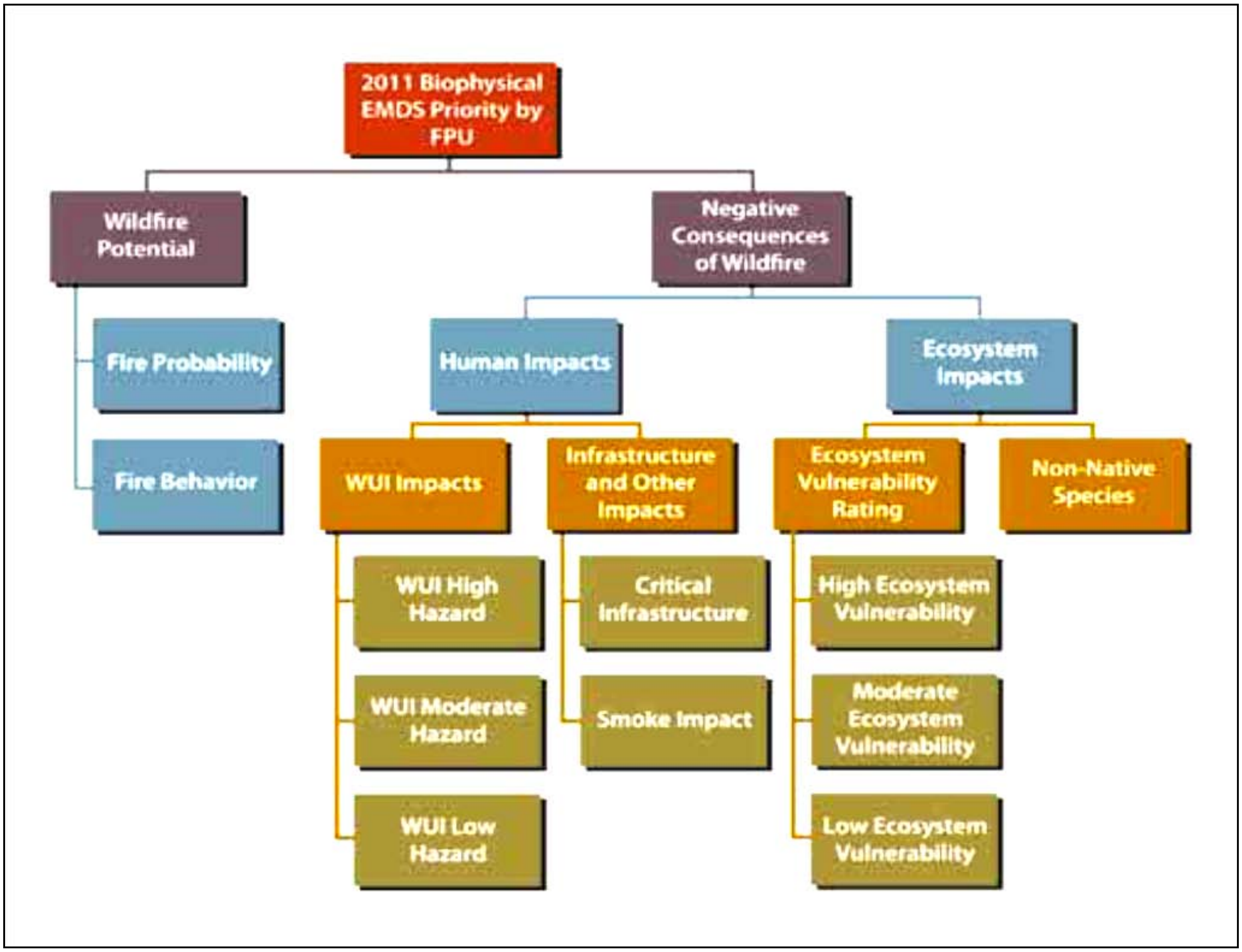


Figure 6-1. Schematic of EMDS Model.

The EMDS first estimates two "elements" — wildfire potential and negative consequences of wildfire — for each of the 136 Fire Planning Units (FPUs) in the 48 contiguous states, Alaska, Hawaii, and seven Territories. The calculation for wildfire potential is based upon estimates of the burn probabilities and fire behavior, as characterized by flame lengths derived from the Large Fire Simulator (FSim). The negative consequences are based on human impacts and ecosystem impacts. The former, human impacts, are based on the hazard (low, moderate, or high) projected in the WUI, and effects on critical infrastructure and from smoke. Ecosystem impacts are obtained using effects on grass, forest, shrub cover,[d] and on non-native species. The two elements, and their determinants, are then weighted to help develop priorities.[227] The weights, which are applied consistently across all FPUs, are assigned by a consensus of the Interior Fire Executive Council (IFEC). This approach

[d] The ecosystem impacts on various cover is based on simultaneous consideration of the type of cover, the fire regime condition class (FRCC), and the fire return interval. The FRCC is a standardized tool for determining the degree of departure from reference condition vegetation, fuels and disturbance regimes.

allows each FPU to be ranked (for practical purposes). The USFS also uses EMDS, but with different weights.[228]

In parallel with this, specific projects that have been nominated to receive funding are scored using the Project Priority System (PPS). The scores are based upon a wide variety of "attributes" designed to assess the degree to which each proposed project is expected to achieve HFR program priorities as outlined by the DOI Assistant Secretary for Policy, Management and Budget (PMB). Attributes include, for example, whether and the extent to which the project can be expected to mitigate the effects of wildfires on communities; whether it would advance firefighter safety; whether the fuels reduction treatments are priority as determined by a community wildfire protection plan or equivalent; and project effectiveness and cost per acre.[229] Scores for each attribute are summed to give a total score under the PPS.

The EMDS and PPS scores are then combined by giving them equal weights. The final results are then used to help allocate funding for hazardous fuels reduction projects among the bureaus.

Section Summary

There is a long history of modeling various aspects of wildland fire within the USFS and DOI. Many of these models have been integrated and enhanced to develop decision support systems which can be used to inform policy and budgeting decisions. Table 6-1 presents a brief summary of some of the more common fire behavior models, fire effects models, and decision support systems currently in use or under further development.

Table 6-1 Fire Model Comparison

Model	Description	Inputs	Outputs
BehavePlus	A fire behavior prediction and fuel modeling system which models "fire behavior (such as rate of spread and spotting distance), fire effects (such as scorch height and tree mortality), and the fire environment (such as fuel moisture and wind adjustment factor)."[230] Assumes conditions are constant and uniform for each time step.	Surface size, fuel/vegetation, surface/understory, fuel moisture, weather, terrain, fire. Interactive user input; generally ranges of values.	Rate of speed, flame length, fire area, and perimeter.
FlamMap	"FlamMap is a fire behavior mapping and analysis program that computes potential fire behavior characteristics (spread rate, flame length, fireline intensity, etc.) over an entire FARSITE landscape for constant weather and fuel moisture conditions."[231] Includes an option for mapping minimum travel time and fuel treatment options[232]	Spatial (GIS) fuel and terrain data, user-defined fuel moisture, weather, and wind, percentage of the landscape to treat, and maximum treatment size. Option for minimum travel time also requires percent of landscape to be treated and maximum treatment size.	Surface fire spread, crown fire initiation, crown fire spread, and map of potential fire behavior for every point on the landscape. Map of minimum travel time pathways, arrival time contours. Fuel treatment placement recommendation.
FARSITE	"FARSITE is a fire behavior and fire growth simulator that incorporates both spatial and temporal information on topography, fuels, and weather. It incorporates existing models for surface fire, crown fire, spotting, post-frontal combustion, and fire acceleration into a 2-dimensional fire growth model."[233]	Spatial information (GIS) on topography and fuels, user-defined fuel moisture, weather, and wind.	Map of fire growth, perimeter, intensity, etc.[234]
NEXUS	"NEXUS 2.0 is crown fire hazard analysis software that links separate models of surface and crown fire behavior to compute indices of relative crown fire potential. Use NEXUS to compare crown fire potential for different stands, and to compare the effects of alternative fuel treatments on crown fire potential." [235]	Existing models of surface and crown fire behavior.	Potential for crown fires at the stand level.

Model	Description	Inputs	Outputs
LANDFIRE	"LANDFIRE (also known as Landscape Fire and Resource Management Planning Tools) is an interagency vegetation, fire, and fuel characteristics mapping program. The program is a long-range initiative to periodically update LANDFIRE data to sustain the value of the original project investment and to ensure the timeliness, quality, and improvement of data products into the future."[236] LANDFIRE can be used in applications such as the Cohesive Strategy, Wildland Fire Decision Support System (WFDSS), Fire Program Analysis (FPA), and Hazardous Fuels Prioritization and Allocation System (HFPAS).	Over 50 spatial data layers in the form of maps and other data that support a range of land management analysis and modeling, including existing vegetation type, canopy, and height; biophysical settings; environmental site potential; fire behavior fuel models; fire regime classes; and fire effects layers.	LANDFIRE produces a comprehensive, consistent, scientifically credible suite of spatial data layers for the entire US.
First Order Fire Effects Model (FOFEM)	"FOFEM provides quantitative fire effects information for tree mortality, fuel consumption mineral soil exposure, smoke and soil heating."[237]	Geographic regions, cover types, and fuel loads.	Fuel consumption, smoke emissions, and soil heating.
Fire & Fuels Extension - Forest Vegetation Simulator (FFE-FVS)	"FFE-FVS links the dynamics of forest vegetation (primarily trees) with models of snag, fuels, and fire behavior. In tracking fuel dynamics, processes such as litterfall, snag fall down, the accumulation of activity fuels, and decomposition are modeled. Fuel loading, forest type, and other stand characteristics, are used to classify stands into one of the standard fuel models used to model fire behavior. Fire behavior is then represented using pre-existing methods — the algorithms in systems such as Behave and Nexus are used internally to estimate surface and crown fire behavior."[238]	Initial fuel loads, dominant cover type, percent cover, fuel moistures, and wind speed.	Fuel dynamics (processes such as litterfall, snag fall down, the accumulation of activity fuels, and decomposition), and fire behavior.
FSPRO	A fire behavior model component of the WFDSS. It is a spatial model that calculates the probability of fire spread from a current fire perimeter or ignition point for a specified time period.[239]	Surface fuel model, aspect, elevation, slope, and canopy characteristics. Uses historical ERC and wind data.	Map of fire spread probabilities for 7-90 days in the future.
RAVAR	A fire effects component of the WFDSS, "RAVAR identifies the primary resource values threatened by ongoing large fire events. RAVAR is typically integrated with the FSPro model to identify the likelihood of different resources being impacted in the potential fire path of an ongoing event but can be linked to any expected fire spread polygon."[240]	County level geospatial cadastral data, aerial photo interpretation, GIS parcel records, and FSPro outputs.	Tier I and tier II maps, representing private structures, public infrastructure, and natural resources at risk.

Model	Description	Inputs	Outputs
Fire Program Analysis (FPA)	"Is a strategic trade-off analysis tool that allows decision makers to investigate the implications of different investment choices. Will reflect fire management objectives and performance measures for prevention, preparedness and hazardous fuels and suppression activities. Is a tool that provides opportunities to evaluate relative trade-offs in alternative fire management strategies."[241] Uses seven performance measures: reducing the probability of occurrence of costly fires, reducing the probability of occurrence of costly fires within the WUI, increasing the proportion of land treated in order to reduce wildland fire risks, protecting highly valued resource areas from unwanted fires, maintaining a high initial attack success rate, decreasing the proportion of land burning above the damaging threshold, and, increasing the proportion of land burning at or below the damaging threshold. The FPA is currently in development. It is planned to go into the operations and maintenance (O&M) phase in June, 2012.	Initial Response Simulation (IRS): Historic fire occurrence records, weather observations, topographic data, LANDFIRE fuels model data, Fire Planning Units (FPU), dispatch locations, initial attack fire line production rates, FPU preparedness options, and FPU fuel treatment options. Large Fire Module (LFM): IRS inputs, common fuel treatment prescriptions, and number of fires exceeding simulation limits.	(IRS): Number of fires contained, number of fires exceeding simulation limits, size of fires, and potential costs. Most fires are successfully contained in Initial Response both in the real world and in the model environment a small proportion, 5%, are not and are then carried over to LFM. (LFM): Burn probability, fire intensity level, large fire costs, effects of fuel treatment, and final fire size. This data is used in national Goal Programming Trade Off analysis to provide managers with information used in national strategic funding considerations.
Ecosystem Management Decision System (EMDS)	EMDS is part of the Hazardous Fuels Allocation and Priority System (HFPAS). It is used to allocate hazardous fuels reduction funds for the four DOI land management agencies, based on wildfire potential, and associated negative consequences. It considers impacts on the WUI, critical infrastructure, smoke effects, ecosystems, and non-native species. It is based on analysis of each FPU, rather than a bureau specific-analysis.	Fire occurrence from Wildland Fire Management Information System and Fire Management Information System; fire return intervals, FRCC, and existing vegetation type (EVT) layer from LANDFIRE; data for WUI; wildfire potential for FPA's Large Fire Simulator; critical infrastructure data	A prioritization of FPUs which is used to allocate appropriated funds for hazardous fuels management.

Model	Description	Inputs	Outputs
		from National Geospatial Agency (NGA) Homeland Security Infrastructure Program (HSIP) Gold data set; DOI land status layer developed by BLM National Operations Center; and subjective weights from DOI fire managers.	
Wildland Fire Decision Support System (WFDSS)	WFDSS is web based application designed to assist fire managers and analysts in making and documenting, strategic and tactical decisions for fire incidents. It has replaced the WFSA (Wildland Fire Situation Analysis), Wildland Fire Implementation Plan (WFIP), and Long-Term Implementation Plan (LTIP) processes.	Google and topographic background maps; LANDFIRE; values (buildings, range allotments, critical habitat); weather; pre-loaded information on strategic objectives, and management requirements, etc.	Decision document.

7. Wildland Fire Data

Overview

The literature identifies data limitations that challenge management efforts as well as the ability to analyze the economic efficiency of fire programs and discern trends. Data on accumulated fuels and fire hazards are often lacking, hampering efficient hazardous fuel reduction.[242] The lack of data classification standards poses additional limitations, particularly for evaluating fire suppression expenditures.[243] Data inaccessibility further hampers analysis.[244] Based on the literature, this section discusses data issues and identifies options for addressing them.

Data Consistency and Availability

The unique nature of each fire is frequently identified as an obstacle to identifying economic impacts and trends. Lynch points out that as a result, only a few data sources remain consistent from fire to fire, and that "[w]ith each new study comes the realization and frustration that costs were probably missed or overlooked in previous case studies and it is too late to recover them."[245] Other data inconsistencies stem from the fact that important fire information is not systematically collected and summarized at the national level – wildfire impacts on tourism, recreation, and health are usually collected by state or local governments; if available, wildfire impacts on wildlife habitat, water quality, watersheds, and cultural or archaeological sites may be collected by federal or state agencies or their field offices; and county offices coordinate information on private property impacts, which may include evacuated communities and rehabilitation of private lands.[246]

GAO identified significant improvements in federal data and research since the year 2000, but identified remaining challenges – targeting fuel reduction efforts, updating fire management plans, measuring and improving performance, wildland fire research (including cost effectiveness), and allocating budgets – which require the availability of consistent and accurate data to address.[247] Gerbert et al. point out that changes in record keeping, evolving budget object classification codes, and the lack of geographic specificity in expenditure data over the years make it difficult to meet these challenges.[248]

Market and Nonmarket Data

The Economic Analysis section of this report reviewed the literature on estimating fire programs' benefits and costs for both market (e.g., structures and timber) and nonmarket (e.g., cultural resources and water quality) goods and services. The literature identifies data gaps, particularly with regard to nonmarket data – the values and quantities of intangible goods and services. Venn and Calkin, focusing on nonmarketed resources, identified five major challenges to analysts' ability to develop data on nonmarket values:[249]

1. Scarcity of scientific information about how nonmarketed resources are affected by wildfire;
2. Limited amenability of many nonmarketed resources affected by wildfire to valuation by benefit transfer;
3. A dearth of studies that have estimated marginal willingness to pay;
4. Violation of consumer budget constraints [adding the willingness to pay estimates of different studies, each evaluating different nonmarket resources that are at risk, is unlikely to be valid]; and
5. Valuation of indigenous cultural heritage is unlikely to be feasible.

As previously discussed, the availability and accuracy of market data also poses analytical obstacles. Post fire estimates of the number and value of threatened and evacuated structures (e.g., public and private) and infrastructure (e.g., recreation areas, highways and power lines), for example, are generally available only for large fires, and limited by inconsistent definitions of what constitutes the terms "threatened" and "evacuated."[250] Studies rarely calculated the long-term socioeconomic impacts, beyond suppression, preventing the assessment of the total benefits and costs of restoration efforts.[251] The limited availability and quality of accurate information on infrastructure and structures has also hampered fire planning and budgeting.[252]

Models

The development and use of models to support fire program decisions requires accurate and up-to-date data, as well as information on resource management practices and the values of market and nonmarket goods and services.[253] Recognizing the link between fire models and data, GAO has emphasized the need for better data and modeling to enable agencies to determine the extent and severity of the wildland fire problem and to allow them to better coordinate their efforts and resources.[254] Gebert et al. believe that better data would improve both the ability to make budget estimates and to understand the factors influencing suppression expenditures.[255] They propose developing an interagency fire occurrence data system with financial system links and more spatially explicit data that includes fire perimeter information and fire characteristics over a broader landscape than the ignition point.

Options for Improvement

Morton et al. identify significant improvements in federal and state data availability and access between the 2000 and 2002 wildfires, but point out that county and local government fire information is not as readily available, especially for older fires.[256] Recent advances in fire behavior modeling and the ability to spatially describe potential values at risk also show promise in providing common frameworks for estimating wildfire risk and probability.[257] DOI and the USFS are addressing federal data access and reliability issues by cooperatively developing a database, the Fire Occurrence Reporting System (FORS), that enables federal agencies to access critical and common fire occurrence data.[258] Calls for increasing financial support to improve data collection,[259] increasing research on nonmarket valuation, particularly with respect to cultural resources and resources that do not provide market-based products,[260] and expanding the National Interagency Fire Center's role in addressing data standards and accessibility[261] have been put forward as options to address data availability, accessibility, and reliability issues. Focusing on improving data to improve economic assessments, Abt et al. call for the following data collection changes:[262]

1. Including cost, damage, and benefit data for all wildfires. [The current practice of including only fires greater than 100 acres or more than $25 million in damages excludes cumulative impacts that can be considerable],
2. Collecting data on structures damaged, destroyed, and threatened, as well as structures evacuated in conjunction with other existing fire records,
3. Recording deaths and serious injuries for all fires,
4. Using a predetermined classification system (based on severity) to record acres burned to assist in developing loss and damage estimates for nonmarket or non-quantified attributes, and
5. Using the same degree of detail to record prescribed fire and other fuel treatment data, perhaps by using the fire records database.

Section Summary
Data limitations are widely recognized as impeding both fire managers and program analysts. While progress has been made, additional actions are needed to improve data quality, availability, and accessibility. Suggested reforms could enable fire managers to more efficiently plan and respond to wildland fires and allow analysts to better estimate the relative effectiveness of the different strategies employed. Policy and decision makers would also benefit from improved information on results.

8. Conclusion

Fire policies and land management have evolved considerably over the last century to incorporate scientific and technological advances, changing management philosophies, and social values. Despite the advances, the literature reflects widespread concern that fire program initiatives do not adequately address the issues and are not cost effective. This literature review, which focused on six topics relevant to fire program management, found the following:

Policy – Policy changes have been the norm for DOI's Wildland Fire Program. Implementing Congress's most recent policy, to shift the emphasis of hazardous fuel reduction funding from the WUI to the highest priority projects and areas, will likely require time to fully implement.

Intergovernmental cooperation in firefighting has improved significantly. However, legal, institutional, and fiscal issues remain.

DOI Budget Trends – DOI's annual obligations have fluctuated depending on the extent of wildland fires and other factors. Over the last decade, DOI's Wildland Fire Program obligations have generally decreased – from $1.2 billion in FY 2002, to $873 million in FY 2011 (adjusted for inflation).

Performance Measures – Performance measures have evolved with changing policies. The number of annual performance measures for DOI's Wildland Fire Program has been reduced in recent years. The literature calls for improving performance measures to more effectively capture the intent of program goals and objectives.

Economic Analysis – One of the greatest challenges with comparing costs and benefits is in characterizing all outcomes in terms of a common metric, such as dollars. However, nonmarket goods and services (e.g., human health, cultural sites, and wildlife habitat) often are difficult to quantify and monetize. Approaches like benefit-cost analysis, cost effectiveness analysis, and focusing on highly valued resources inform decision makers about the tradeoffs they face.

Models – Recent advances in modeling show promise in reducing uncertainties related to fire behavior and fire effects, and in describing potential values at risk. Together these should help better understand and identify trade-offs associated with various decisions related to fire management.

Data Availability – While progress has been made, additional actions are needed to improve data quality, availability, and accessibility.

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