CHAPTER 16

INCENTIVES AND WILDFIRE MANAGEMENT IN THE UNITED STATES

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1. INTRODUCTION

A recent series of severe fire seasons in the United States has contributed to sharply rising wildfire suppression costs. These increasing costs have caught the attention of policy makers, but so far the responses have not focused clearly on the incentive structures that allow or encourage rising costs (National Academy of Public Administration 2002). We analyze the problem of rising suppression costs by examining the incentive structures faced by fire managers. Specifically, we examine the influence of wildfire suppression funding mechanisms on managers' behavior. The rationale for this approach is that fire managers have a good deal of control over suppression costs; they, like other people, respond to incentives; and thus it is through a change in those incentives that fire managers are most likely to change their behavior.

To understand how the current incentive structure for fire managers developed, we begin with a brief history of wildfire management in the United States and an introduction to wildfire suppression budgeting. We then examine how the government-wide movement for increased accountability has led to the use of performance measures in the wildland fire program, and we explore how these have shaped the incentive structures faced by fire managers. Finally, we suggest an alternative incentive structure created through changes in wildfire suppression budgeting.

2. HISTORY

In the late 19th Century, a series of severe fire seasons in the Northeast and the lake states, plus the failure of local efforts to adequately respond to these events, contributed to a call for the federal government to manage wildfire suppression on public land (Pyne 2001). This responsibility initially fell to the Department of the Interior, which received help from the U.S. Army. However, in 1905, Theodore Roosevelt transferred responsibility for wildfire suppression to the Bureau of Forestry, which soon became the U.S. Forest Service headed by his friend Gifford Pinchot. The main mission of the new agency was conservation and the provision of a secure timber supply. One of the main dangers posed by wildfire was the disruption of that supply. In addition, wildfire threatened community water supplies.

Although there was general agreement on the values at risk from wildfire, there was considerable debate about the best way to manage the risk. One approach, often referred to as light burning, advocated fire use to achieve a variety of objectives including hazardous fuels reduction, land conversion for agriculture, and the improvement of game habitat. Light burning was particularly prevalent in the Southeast. In contrast, some, including Gifford Pinchot, advocated a policy of fire control, which emphasized fire suppression and had no place for fire use. This debate over the role of fire on public lands might have continued for longer or resulted in a different outcome had it not been for the 1910 fire season, during which 5 million acres of national forest land burned and 78 people were killed (Pyne 2001). This extreme fire season caused the Forest Service to adopt a policy of strict fire protection and influenced a generation of foresters.

The Forest Service's commitment to fire protection was intended to protect timber and community water supplies. Because of the huge amount of land under its control, the Forest Service had to be selective about the areas it protected. The criterion used to determine which areas to protect, and how much to spend protecting them, was therefore based on timber and water values. This economic principle, that suppression expenditures should be commensurate with values at risk—first formally presented by Sparhawk (1925)—became known as the "least-cost-plus-loss" model. Simply put, the most efficient level of fire management expenditure is the one that minimizes the sum of all fire-related costs and damages.

The late 1920s and early 30s saw more extreme fire seasons (Gorte and Gorte 1979), the losses from which led fire managers to the conclusion that they had not been sufficiently aggressive in fighting fires. They reasoned that because the values at risk from wildfire were so high, a more aggressive fire suppression effort, with a focus on strong initial attack, would be consistent with the least-cost-plus-loss model (Hornby 1936).

This shift in attitudes may not have been sufficient to fundamentally alter wildfire management, had it not coincided with the Great Depression and Roosevelt's subsequent New Deal. The New Deal had two profound impacts on wildfire management. First, the Forest Service acquired significant new land holdings. Second, the Civilian Conservation Corp (CCC) provided a huge increase in manpower available for wildfire suppression. This expansion in manpower allowed the Forest Service to extend fire protection to previously unprotected and newly acquired land. However, much of this land had little if any market value, as it was often abandoned farmland or cutover forestland. Therefore, if the Forest Service was to make use of the influx of manpower provided by the CCC, it would explicitly have to set aside the economic principal of protecting land commensurate with the values at risk. This example of the resource availability tail wagging the policy dog is succinctly summarized by Pyne et al. (1996, p. 248): "…the means at hand were often so powerful as to dictate to some extent the ends to which they might be applied".

This change of policy was codified in 1935 by the 10AM policy (Gorte and Gorte 1979, p. 2):

> *"The approved protection policy of the National Forests calls for fast, energetic, and thorough suppression of all fires in all locations, during possibly dangerous fire weather. When immediate control is not thus attained, the policy calls for prompt calculating of the problems of the existing situation and probabilities of spread, and organizing to control every such fire within the first work period. Failing in this effort, the attack each succeeding day will be planned and executed with the aim, without reservation, of obtaining control before ten o'clock the next morning."*

This new policy of aggressive suppression, which mentions neither suppression costs nor resources at risk, was embodied in 1944 by the successful Smokey the Bear public education campaign. A more emotive example of the prevailing attitudes to wildfire was provided by the death of Bambi's mother in 1943. Interestingly, Walt Disney intended Bambi to be an anti-hunting film: careless hunters started the fire. However, the potency of the fire imagery overwhelmed the original message.

The period following the Second World War provided a further example of resource availability driving wildfire policy and practices. The Forest Service received numerous war-surplus vehicles and aircraft under the federal excess equipment program and was able to increase its use of fire engines and bulldozers. In 1955 converted aircraft were used to drop fire retardant for the first time (Pyne, Andrews et al. 1996). As with the earlier use of the CCC, this increased use of vehicles and aircraft was driven by resource availability, not by any analysis showing that these increased expenditures would result in a commensurate reduction in resource damages. Aggressive suppression of wildfire was also consistent with the cold war social contract: people expected the government to protect them from harm.

Not until the 1960s did the Forest Service waver from its policy of aggressive wildfire suppression. As reflected by the passage of the Multiple-Use Sustained-Yield Act (1960), the Wilderness Act (1964), and the National Environmental Policy Act (1970), attitudes concerning public lands management had begun to shift (Dale et al. 2005). These changes in public attitudes may or may not have been sufficient to change Forest Service suppression policies. However, the Forest Service was also facing scrutiny for a more prosaic reason—decades of increasing suppression expenditures had not resulted in a decrease in resource damages. The inability of the agency to demonstrate a sufficient return on its investment in fire suppression resulted in a series of policy changes in the 1970s (Gorte and Gorte 1979).

In 1971 the 10AM policy was amended, the new goal being to contain all fires before they reached 10 acres, and then the entire policy was scrapped in 1978. Also in 1978, Congress eliminated emergency funding for pre-suppression. Although the agency still relied on emergency funds to pay for large fire suppression, the new protocol required the Forest Service instead to conduct a cost-benefit analysis on all future presuppression budget requests. This led to the 1979 development of the National Fire Management Analysis System (NFMAS), a computerized fire planning and budgeting tool. As a further incentive, the Forest Service's budget was reduced by 25% until it could more rigorously support its budget requests. Other public land management agencies either adopted all or part of NFMAS (Bureau of Land Management and the Bureau of Indian Affairs) or developed their own tools (National Park Service and the Fish and Wildlife Service). NFMAS was the first widely adopted computerized fire management tool (Donovan et al. 1999).

The realization that not all suppression expenditures could be economically justified, along with an increasing awareness of the ecological importance of wildfire, led the Forest Service to adopt the Wilderness Prescribed Natural Fire Program in 1972 (Dale et al. 2005). Under the program some wildfires in wilderness areas were allowed to burn. In 1968 the National Park Service recognized the natural role of fire, and adopted a wildfire use program beginning in Sequoia Kings Canyon National Park. Since then, several high profile examples of prescribed or wildfires being managed for resource benefit have escaped management control and become destructive wildfires (e.g., Yellowstone in 1988 and Los Alamos in 2000). These well-publicized incidents have tempered enthusiasm for wildfire use both within the agency and among the public at large.

The success of decades of fire suppression has deprived fire-dependent forests of their natural fire cycle and has led to an accumulation of fuels in many locations (Arno and Brown 1991). Furthermore, the country has seen a dramatic increase in the number of houses and other structures being built in the forest, expanding the extent of the wildland-urban interface (NAPA 2002). Both of these stresses have tended to make fires more difficult and expensive to control. And recently, a severe drought in the Western U.S. exacerbated the situation. In 2000, total federal wildfire suppression expenditures exceeded $1 billion for the first time, and they have done so twice since (Table 16.1).

In recent years appropriated dollars for fire suppression have fallen far short of total suppression expenditures. In addition, emergency appropriations, which take place after final appropriations bills have been released, often failed to make up the shortfall. As a result, agencies have been forced to borrow money from other programs to fund their suppression activities. Although attempts are made to reimburse programs that have had funds transferred, these repayments are rarely in full (Chapter 17). The disruption and uncertainty associated with suppression funding transfers have compounded inefficiencies and led to numerous cancelled projects.[1]

[1] The Government Accountability Office, analyzing this trend, concluded, "Despite Forest Service and Interior efforts to minimize the effects on programs, transferring funds caused numerous project delays and cancellations, strained relationships with state and local agency partners, and disrupted program management efforts" (GAO-04-612. *Wildfire Suppression: Funding Transfers Cause Project Cancellations and Delays, Strained Relationships, and Management Disruptions* p3).

Table 16.1. Nominal wildfire suppression expenditures by land management agency 1994 to 2004

Year	Bureau of Land Management	Bureau of Indian Affairs	Fish and Wildlife Service	National Park Service	USDA Forest Service	Total
2004	$147,165,000	$63,452,000	$7,979,000	$34,052,000	$637,585,000	$890,233,000
2003	$151,894,000	$96,633,000	$9,554,000	$44,557,000	$1,023,500,000	$1,326,138,000
2002	$204,666,000	$109,035,000	$15,245,000	$66,094,000	$1,266,274,000	$1,661,314,000
2001	$192,115,000	$63,200,000	$7,160,000	$48,092,000	$607,233,000	$917,800,000
2000	$180,567,000	$93,042,000	$9,417,000	$53,341,000	$1,026,000,000	$1,362,367,000
1999	$85,724,000	$42,183,000	$4,500,000	$30,061,000	$361,000,000	$523,468,000
1998	$63,177,000	$27,366,000	$3,800,000	$19,183,000	$215,000,000	$328,526,000
1997	$62,470,000	$30,916,000	$2,000	$6,844,000	$155,768,000	$256,000,000
1996	$96,854,000	$40,779,000	$2,600	$19,832,000	$521,700,000	$679,167,600
1995	$56,600,000	$36,219,000	$1,675,000	$21,256,000	$224,300,000	$340,050,000
1994	$98,417,000	$49,202,000	$3,281,000	$16,362,000	$678,000,000	$845,262,000

Source: National Interagency Fire Center (www.nifc.gov/stats/suppression_costs.html)

The wildfire situation—accumulating fuels, rising costs, and budget disruption—suggests that significant changes in the management of wildfire suppression are warranted. Rising federal budget deficits and shrinking discretionary spending make the need for reform more urgent. Before we examine proposed changes, we review the current funding structure.

3. FUNDING WILDFIRE SUPPRESSION

Wildfires can have both negative and positive effects. Negative effects, or damages, may include loss of timber, damage to structures, loss of tourism revenue, and temporary reduction in water and air quality. Positive effects, or benefits, may include nutrient cycling, enhancement of the long-run success of native fire-adapted trees and plants, and a reduction in fuel loads. A wildfire that reduces fuel loads reduces the severity of future wildfires,[2] thereby reducing future wildfire-related damages and suppression costs. Conversely, wildfire suppression allows fuel loads to grow, thereby increasing the sum of future wildfire damages, suppression costs, or fuel treatment expenditures. Thus, an increase in the level of suppression leads to a decrease in *both* the damages and the benefits of wildfire.

The relation between fire fighting cost (C, the sum of presuppression cost and suppression cost), fire damage, and fire benefits can be represented graphically as in Figure 16.1. In the figure, the value of all wildfire damages minus the value of all wildfire benefits is shown as the net value change (NVC) (Donovan and Rideout 2003, Chapter 18). Holding presuppression cost fixed at $X, the optimal amount of suppression minimizes the sum of C and NVC (C+NVC) at level S*.

This minimization problem is represented mathematically as:

$$MIN: \quad C + NVC = W^p P^e + W^s S^e + NVC(P^e, S^e), \qquad 16.1$$

where P^e denotes presuppression effort, S^e denotes suppression effort, W^p denotes the wage of presuppression, and W^s denotes the wage of suppression. Differentiating with respect to P^e and then S^e gives the following first-order conditions:

$$\frac{\partial(C + NVC)}{\partial P^e} = W^p + \frac{\partial NVC}{\partial P^e} = 0, \qquad 16.2$$

$$\frac{\partial(C + NVC)}{\partial S^e} = W^s + \frac{\partial NVC}{\partial S^e} = 0. \qquad 16.3$$

[2] Wildfires can increase the severity of future wildfires in the short run, if the wildfire causes significant mortality and an increase in fuel loads. However, in the long run, regular wildfires will generally reduce wildfire severity.

Rearranging the terms yields:

$$\frac{\partial NVC}{\partial P^{e}} = -W^{p}, \qquad 16.4$$

$$\frac{\partial NVC}{\partial S^{e}} = -W^{s}. \qquad 16.5$$

Of course, Figure 16.1 and equations 16.1–16.5 are an abstraction. Fire managers face uncertainty about fire behavior, suppression effectiveness, and resource damages, and therefore must base their decisions on less information than is implicitly contained in Figure 16.1 or equations 16.1–16.5. However, the model does provide a rule of thumb: an additional dollar should only be spent on presuppression or suppression if it averts at least one dollar of NVC.

The Forest Service funds presuppression and suppression efforts in different ways. Until approximately 2005 presuppression budgets were developed using NFMAS, a simulation model that allows users to compare the effect of alternative suppression strategies on historical wildfires. Sine that time, the Forest Service

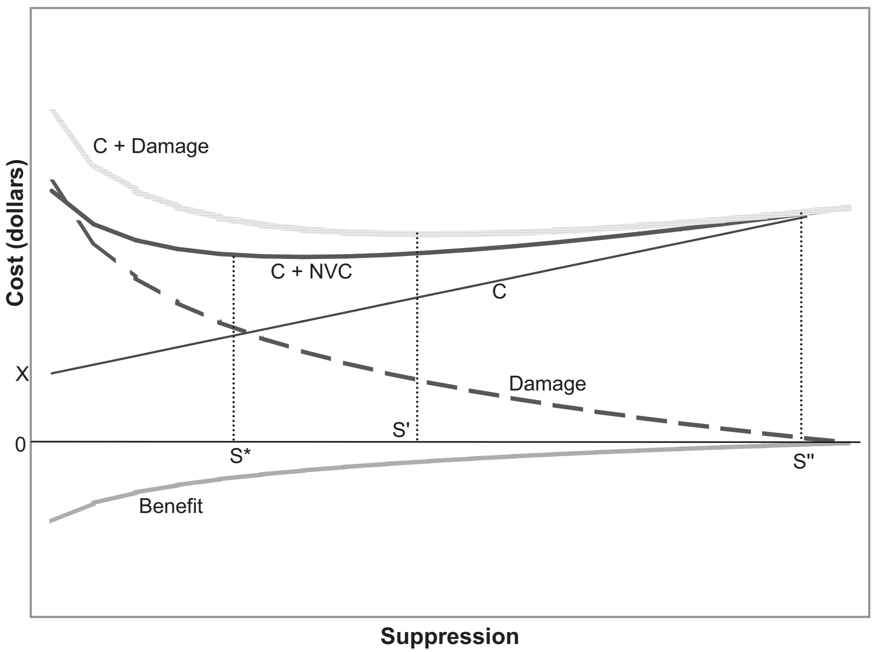

Figure 16.1. A comparison of optimal suppression expenditure and suppression expenditure under current incentive structure (C=Suppression plus presuppression cost, X = fixed presuppression cost. Benefits are negative relative to costs).

and other land management agencies have begun the process of developing and implementing a new interagency wildfire planning and budgeting tool called the Fire Program Analysis system. Under NFMAS or the Fire Program Analysis System, presuppression budgets are set early in the year and are generally spent regardless of the number of fires that ultimately occur. The suppression budget, however, begins with an initial appropriation that in a mild fire year may not be totally spent and that in a severe fire year can be supplemented with emergency suppression funds. The Forest Service bases its suppression budget request on a 10-year moving average of total suppression expenditures (chapter 17).

Most wildfires are contained by suppression efforts within the first 12-hour burning period (often referred to as initial attack). Those that are not are considered “escaped fires”. Although few fires escape, those that do account for the great majority of burned acres and suppression expenditures (USDA 2003b).

The suppression of large escaped wildfires is undertaken jointly by local land managers and incident command teams. Incident command teams assume responsibility for tactical wildfire suppression decisions, although local land managers provide overall strategic guidance. To determine the appropriate suppression strategy, local land managers are required to perform a wildland fire situation analysis (WFSA). A WFSA requires a manager to consider different suppression strategies, associated costs and damages, probability of success, and the compatibility of these strategies with established land management objectives. For example, in a situation where significant volumes of commercial timber are at risk and the weather forecast predicts hot, dry, windy weather, a manager may recommend that the incoming incident command team use an aggressive suppression strategy. However, if a wildfire does not significantly threaten resources of particular management concern or the weather forecast is favorable, a less aggressive strategy may be recommended. Anecdotal evidence suggests that managers may sometimes use WFSA more as a decision justification tool. That is, managers decide in advance what strategy they wish to employ and then use the WFSA process to justify this decision (Donovan and Noordijk 2005).

A WFSA provides the incoming incident command team with strategic guidance and a non-binding estimate of suppression cost, which can be reassessed if fire conditions change. Notably, when preparing a WFSA, managers are directed not to consider the potential beneficial effects of wildfire. Incident commanders also are directed not to consider beneficial fire effects when planning or executing suppression activities. But even if land managers and incident commanders were free to consider the beneficial effects of wildfire, it is unlikely that they would accord them sufficient weight. Wildfire damages are immediate, and both land managers and incident commanders face intense pressure to minimize those damages. In contrast, the benefits of wildfire are only partially understood, nearly impossible to quantify, and occur in the future.

Disregard of the beneficial effects of wildfire creates an incentive to increase suppression expenditures beyond the efficient level (S*) shown in Figure 16.1. When the beneficial effects of wildfire are ignored, the optimal level of suppression becomes S'. The magnitude of the difference between S* and S' will of course depend on the functional relationship between wildfire damages and benefits and suppression expenditures.

Funding wildfire suppression with an emergency suppression budget provides fire managers with an additional incentive to over-utilize suppression resources, as the opportunity cost to fire managers of suppression expenditures is zero. If fire managers were to forgo some increment of suppression spending, the savings would not remain within the fire or fuels management budget. Therefore, unless suppression resources are simply unavailable, fire managers may continue to spend on suppression as long as their efforts decrease damage by even a small increment. If all needed resources are available, suppression expenditures may reach S" in Figure 16.1: the point where all damages are theoretically averted.

In summary, the current Forest Service mechanism for funding wildfire suppression has two related problems. First, the benefits of wildfire are ignored. Second, the opportunity costs of wildfire suppression expenditures are not fully considered. Both problems encourage fire managers to use inefficiently high levels of suppression expenditure. In essence, the budget (B) that fire managers have to use in a given year, say year 1, is:

$$B_1 \leq P_1 + S_1 + E_1 \qquad 16.6$$

where P is the presuppression budget, S is the suppression budget, and E is emergency spending. The budget in year 1 (B_1) is independent of expenditures in other years, and surplus budget is returned to the treasury. Thus, in a year with unexpectedly few wildfires E equals 0 and suppression expenditure is less than S, and in a year with more wildfires than expected all of S is spent and E is greater than 0. Because of the possibility of emergency funding, the fire manager's choice of suppression effort on one fire is independent of suppression decisions (or, more precisely, expected suppression decisions) on all other fires during the current fire season or any future fire season. Since 2002 managers have been required to meet some of the cost of emergency wildfire suppression with transfers from other programs. Although this may affect managers' decisions on a given wildfire, suppression decisions across wildfires likely remain independent.

We do not mean to imply that fire managers completely ignore opportunity costs. There is considerable emphasis on cost containment within the agency, and undoubtedly fire managers give consideration to complying with this request. However, current wildfire suppression budgeting policy provides little or no serious incentive for fire managers to consider the costs of suppression resources (or the beneficial effects of wildfire). In the heat of battle, the pressures are to contain damage, not costs, and funds are generally made available when requested. It is within this light that we consider two alternatives for improving the incentive structure. First we look at the use of performance measures, a process that has recently been introduced to various federal government agencies to improve budget decision making and accountability. Then we examine an idea that has not yet been implemented, but which may hold promise as a way to raise the importance of both cost containment and consideration of the benefits of wildfire.

4. PERFORMANCE MEASURES

In 1993, Congress passed the Government Performance and Results Act to improve congressional oversight of federal expenditures by tying appropriated dollars to measurable results (www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html). Under this act, all federal agencies have (since 1997) been required to submit five-year strategic plans, which identify planned accomplishments and the performance measures used to judge progress towards these accomplishments; an agency's future budget may be dependent on being able to demonstrate such progress. For example, field staff track the "number of acres treated" for hazardous fuels reduction. These numbers serve both to assess progress in the program to date and to help budget planners predict necessary funding for future budget cycles. Although performance measures are intuitively appealing, designing effective performance measures is not easy. We first discuss these difficulties in general and then use this discussion to illustrate problems with performance measures used to evaluate the Forest Service's wildfire suppression program.

There are two main problems encountered when designing performance measures. First, a performance measure may require data that are difficult if not impossible to collect. If progress towards a goal cannot be readily measured, then managers have little incentive to direct resources towards that goal. Second, a performance measure may not be a good indicator of progress towards the goal it was intended to measure. To illustrate this point, consider the difference between *outputs* and *outcomes*. Outcomes are the desired goals that an agency is working to achieve. However, these outcomes are often long-term and difficult to quantify, for example, increasing forest health or reducing wildfire risk. Therefore, an agency often selects a more easily measurable intermediate output as a performance measure, for example, the number of acres that receive a certain land management treatment. If the performance measure is not a good indicator of progress towards a particular outcome, then the agency may not allocate its resources efficiently—emphasizing the intermediate output at the expense of actions that would better achieve the desired final outcome.

The Forest Service currently uses 17 performance measures to assess its wildland fire management program. Of these, three directly address wildfire suppression costs (Table 16.1), and are intended to minimize those costs subject to safety and resource constraints. The first performance measure encourages managers to spend suppression resources commensurate with the values at risk. However, to demonstrate that a suppression strategy does this, a manager must show what a fire would have done in the absence of the suppression strategy and must place a monetary value on resource damages. The data required to complete both of these tasks are incomplete at best, and, therefore, managers may not be able to reliably demonstrate progress under this performance measure. Problems implementing this performance measure illustrate the need to develop better resource value measures. The second and third performance measures encourage aggressive initial attack, as fires are easier and cheaper to control when they are small. However, these two performance measures do not encourage managers to consider the benefits of wildfire. A century of aggressive wildfire suppression has led to elevated fuel loads on the nation's forests and has contributed to the recent increase in suppression costs (Calkin, Gebert et al. 2005). Therefore, the type of wildfire management encouraged by these two performance measures, although it may minimize short term suppression costs, may contribute to an increase in long term suppression costs and may adversely affect forest health. In other words, the desired outcome of minimizing long term suppression costs becomes subordinate to reducing short run suppression costs.

The Forest Service's current performance measures are not final. As OMB noted in its 2004 program review, "discrete targets and baseline data have not been developed for either annual or long-term goals, and some performance measures are vague and in need of greater definition."[3] Another analyst has noted that measures being tested by the Forest Service lack clarity, combine activities, miss important qualitative achievements, fail to capture important activities, count only a portion of what has been accomplished, and provide data that is difficult to interpret.[4] These problems demonstrate that designing a system of performance measures that provides the desired incentives for managers is not straightforward, and that some performance measures may introduce unintended and unwanted incentives.

5. INCENTIVES AND THE WILDFIRE SUPPRESSION BUDGET

Recognizing that performance measures may not provide adequate incentives to reduce suppression costs, we examine another approach to the two identified problems—lack of attention to the benefits of wildfire and the opportunity cost of emergency suppression expenditures. This approach uses the budget process to fashion manager incentives.

Consider first simply eliminating emergency spending, which produces the following annual budget:

$$B_1 \leq P_1 + S_1 \tag{16.7}$$

[3] FY04 Budget Fall Review, OMB PART Review.

[4] Gorte, Ross. 2000. Testimony before the House Resources Committee Subcommittee on Forests and Forest Health: *Forest Service Performance Measures* June 29, 2000.

Under this funding mechanism, if S_1 is low enough to constrain suppression expenditure, the budget provides fire managers with an incentive to consider the tradeoff between suppression costs and damage averted; managers would seek to use limited funds where they were most effective. However, this simple approach ignores a major problem—uncertainty about the severity of a fire season would make it impossible to properly set the optimal level of S_1 in advance.

A solution to the problem of determining a suppression budget for an uncertain fire season is to set P and S constant for multiple seasons and allow fire managers to carry over surpluses and deficits from year to year. Therefore, savings from a mild fire year could be used to supplement suppression expenditures in a severe fire year:

$$B_1 = P_m + S_m + \left(C_0 - C_1\right) \quad 16.8$$

where C_0 is carryover from the previous year and C_1 is carryover from this year to the next. For example, if a manager receives \$5 million in carryover from the previous year (C_0) and carries over \$2 million to the next year (C_1), then the net carryover (C_0- C_1) is \$3 million. As long as managers expected their base funding (P_m + S_m, *where* the *m* indicates multiple season amounts) to remain constant (in real terms) from year to year, this funding mechanism would provide an incentive to consider the tradeoff between suppression costs and damages averted, and would address the issue of budgeting for an uncertain fire season. P_m and S_m would have to be carefully set based on fire cost history and the overall objectives of the fire suppression policy. (We defer to later the consideration of what is perhaps the more difficult task for the agency and Congress—to stay with the preset budget levels.)

We turn now to the other deficiency of the current system—the lack of an incentive to consider the beneficial effects of wildfire. Various approaches can be imagined for attempting to achieve this aim. We present one offered by Donovan and Brown (2005), which is to add a severity adjustment based on the number of acres burned in a fire season:

$$B_1 = P_m + S_m + \left(C_0 - C_1\right) + bA \quad 16.9$$

where *b* is a constant and *A* is acres burned. *A* is a function of suppression effort. It is assumed that $dA/dS \leq 0$. The Forest Service currently uses a severity adjustment if a region is expected to experience a severe fire season. However, this adjustment is to presuppression budgets and is based on anticipated severity not actual acres burned.

To illustrate how this severity adjustment provides an incentive to consider the beneficial effects of wildfire, consider the cost of suppressing a specific wildfire (c) implied by equation 16.9:

$$c = W^s S^e + b(q - A) \quad 16.10$$

where q is the number of acres the wildfire would burn in the absence of suppression (so $A \leq q$). Equation 16.10 shows that as suppression expenditures reduce the number of burned acres (i.e., as A gets smaller), a fire manager's budget is reduced. For example, consider a forest with a base suppression budget of \$50,000, where a wildfire starts that would burn 1,000 acres in the absence of suppression. If b were chosen to equal the per-acre benefit of wildfire, which in this case we assume is \$50, then the fire manager's maximum suppression budget would be \$100,000 (\$50,000 base + \$50 • 1,000). If the manager spent \$20,000 suppressing the wildfire, reducing the total number of burned acres to 900, the manager's total suppression budget would be reduced to \$75,000 (\$50,000 – \$20,000 + \$50 • 900). Therefore, the cost of suppressing the wildfire would be \$25,000: \$20,000 in direct suppression costs and \$5,000 in reduced budget. The reduction in budget of \$5,000 is a proxy for the wildfire benefits that were foregone by suppressing fire on 100 acres of forest. Therefore, although the fire manager does not directly consider the benefits of wildfire, the manager does consider the reduction in budget from reducing the number of burned acres. In this simple example we assume that all acres have equal wildfire benefits. However, the proposed incentive structure can accommodate different levels of wildfire benefits in different areas. Of course, this reinforces the need for a better understanding of resource values and how these values are affected by wildfire.

To illustrate this point more formally, consider the fire manager's benefit function for a specified wildfire:

$$TB = r(q - A), \tag{16.11}$$

$$TC = W^s S^e + b(q - A) \tag{16.12}$$

where r denotes the per-acre value of resources at risk. Differentiating equations 16.11 and 16.12 with respect to S^e yields the following expressions for marginal cost (MC) and marginal benefit (MB) of suppression:

$$MB = -\frac{dA}{dS^e} r\,. \tag{16.13}$$

$$MC = W^s - \frac{dA}{dS^e} b\,, \tag{16.14}$$

Equating equations 16.13 and 16.14 and rearranging terms yields the following equilibrium condition:

$$\frac{dA}{dS^e} r - \frac{dA}{dS^e} b = -W^s\,. \tag{16.15}$$

The first term on the left hand side of equation 16.9 is the product of the marginal physical effectiveness of suppression and the per-acre value of resources at risk, and is, therefore, the marginal benefit of suppression. Now consider the second term on the left hand side of equation 16.15. If *b* is chosen to be the per acre benefit of wildfire, then this expression, with its negative sign, becomes the marginal loss of wildfire benefits, and the left hand side of equation 16.15 becomes the marginal effect of suppression on NVC. Therefore, if *b* is set to equal the per-acre benefit of wildfire, equation 16.15 is the same as equation 16.5—the first order condition for optimal level of suppression expenditure—and, at the margin, the proposed incentive structure will promote an efficient level of suppression expenditure. Assuming as stated earlier that $dA/dS \leq 0$, fire managers would—via the incentive to maintain budget for suppressing future, potentially more destructive fires—consider the opportunity cost of preventing an acre of land from burning. That is, when the value of the potential damage was judged to be less than direct suppression costs plus the value of the funds that suppression would remove from future suppression activities, managers would avoid the cost and let some acres burn.

We have shown that if *b* is chosen to be the per acre benefit of wildfire, then, at the margin, the proposed incentive structure promotes the efficient use of suppression resources. However, the benefits of wildfire are difficult to accurately quantify, and in any case, because they are in part nonmarket goods, they are difficult to value. A practical approach to setting *b* is to determine how much it would cost to achieve these benefits by different means. The two main management tools for mimicking the beneficial effects of wildfire are prescribed fire and mechanical treatment. The cost of these tools can vary from less than $100 per acre for prescribed fire to over $1000 per acre for mechanical treatment (Hesseln, Donovan et al. 2006). Therefore, the optimal value for *b* varies by site depending on whether prescribed fire is an option and on the difficulty of applying whichever treatment is chosen.

A logical extension to this incentive structure would be to remove the artificial delineation between wildfire and fuels management. In this case, the budget constraint would apply to both wildfire and fuels management, so that *A* represents burned acres plus treated acres. Therefore, if the increase in budget from burning or treating an additional acre (*b*) were larger than the sum of the treatment cost and any damages caused, the manager would treat that acre of land. Another extension to the model would be to remove the distinction between presuppression and suppression budgets. Fire managers would receive a single fire management budget, which could be used to finance suppression, presuppression, or fuels management. These extensions can be incorporated into the model presented; although they do make the model somewhat cumbersome, they do not fundamentally change the results.

An incentive structure that encourages fire managers to increase the number of burned acres would increase the possibility of wildfires or prescribed fires escaping management control and causing unexpected damage. Measures may need to be taken to encourage fire managers to accept this increased risk. Managers should not face undue consequences if a wildfire or prescribed fire they are managing causes unexpectedly high damages. In addition, managers may need additional decision support tools to help them identify and mitigate risk.

Implementing the proposed incentive structure would also require institutional changes. Currently, the local land manager cedes tactical fire management decisions to the incoming incident command team. But for the proposed incentive structure to work, the local land manager must maintain control over suppression decisions. However, incident command teams have far more experience than local land managers in managing large wildfires. Therefore, the proposed incentive structure would require establishing some form of principal-agent relationship between the local land manager and the incident command team.

6. DISCUSSION

The current system for funding wildfire suppression in the United States has evolved over one hundred years in response to changes in the forest landscape, changes in societal values, increasing development in the wildland urban interface, and a number of exogenous factors such as the increased availability of mechanized equipment following the Second World War and the Korean war. We identify two problems with the current system. First, funding wildfire suppression with emergency suppression funds provides little incentive for cost containment. Second, the benefits of wildfire are not given adequate consideration. Both problems contribute to inefficiently high levels of suppression expenditure, which contribute to elevated fuel loads, leading to future wildfires that are more difficult and expensive to suppress.

Performance measures are being adopted by the Forest Service partly to help control suppression expenditures. However, as these performance measures encourage aggressive wildfire suppression, they may contribute to increased suppression costs in the long term. Furthermore, because progress toward desired outcomes is difficult to quantify, the performance measures often focus instead on intermediate outputs that may not adequately represent the desired outcomes.

There are additional problems with the use of performance measures as a cost containment strategy for wildfire suppression. It is not clear how managers will be rewarded for meeting performance targets. Conceptually, performance measures should tie closely to budget allocations; in the case of fire suppression, there is no evidence that this feedback loop exists. Managers may receive budget increases, but nowhere is this explicitly stated. It is also possible that if managers are seen to meet performance targets too easily, then their budgets may be reduced. Therefore, managers may not try to exceed a performance target, because this might lead to an increase in the performance target or a decrease in budget. An additional problem is that performance measures are insensitive to unique local conditions. For example, consider the measure that encourages

Table 16.2. Performance measures relavant to fire suppression costs.

Objective: "Consistent with resource objectives, wildland fires are suppressed at a minimum cost, considering firefighter safety, benefits, and values to be protected."[1]

Performance Measure	Line-up with Outcome?	Incentives created?
The percent of large fires in which the value of resources protected exceeds the cost of suppression.	*No.* This measure is not accurately assessed, is done *ex post facto* with computer models, fails to account for fire benefits, and does not provide any useful tool for line managers during a fire.	Unclear. Fire managers are unlikely to stop fighting a fire just because they notice that there is little commercial timber value on site.
The number of acres burned by unplanned and unwanted wildland fires.	*Yes.* Extinguishing fires while they are small will keep acreage numbers low.	Strong incentive for initial attack.
The percent of unplanned and unwanted wildland fires controlled during initial attack.	*Yes.* Fires are most easily stopped with a strong initial attack while they are small. *No.* Although overall costs may be reduced, spending a lot of money in initial attack translates into very high cost/acre numbers.	Aggressive initial attack on all fires. This measure also functions as a disincentive for fire use, since a "wait and see" management response is specifically discouraged here.

[1] Strategic Plan, p6

Source: 2004 USDA Forest Service budget request. Available at: www.fs.fed.us/budget_2004/documents/FY04_Budget_Just.pdf

strong initial attack. A manager might have the opportunity to let a wildfire burn a larger area to generate resource benefits, but under the performance measure this would be considered a failure. Similarly, moderate weather conditions at the end of a fire season may make it cost effective to let a fire burn for longer than would be the case earlier in the fire season, but again this would be considered a failure.

We present an alternative approach that does not involve measuring managers' performance. Rather, we suggest a funding mechanism that encourages managers to spend their wildfire suppression budgets efficiently in light of the costs and benefits of wildfire suppression. Many of these costs and benefits are not easily measured in monetary terms. However, local land managers are best placed to make these tradeoffs; they are familiar with the diverse benefits generated by the land they administer and how these benefits may be affected by wildfire. In addition, they have an understanding of the relationship between the land and local communities. In summary, we suggest providing land managers with incentives to use suppression budgets efficiently, and then allow them to use their professional judgment when making suppression decisions.

The proposed funding mechanism for wildfire suppression encourages efficient resource use at the margin, but does not help determine the optimal *total* wildfire suppression budget. However, identifying the optimal wildfire suppression budget is perhaps more of a political than an economic question. For example, a reduction in wildfire suppression spending will result in an increase in wildfire damages at least in the short term. These damages would include loss of homes, increased smoke, and a reduction in recreational opportunities. Tools exist for estimating the economic cost of these damages, but what is probably more important is the extent to which the public and their political leaders will tolerate these losses. The task of determining the optimal total suppression budget would, therefore, become an iterative political process balancing wildfire damages and suppression budgets. Wildfire budgets would be determined in much the same way as other public programs such as education or defense.

This chapter dealt exclusively with wildfire management; however, some of the lessons learned may be applicable to other natural disasters. For example, although fixed budgets are not appropriate for natural disasters, we can still provide incentives to encourage the efficient use of resources. In addition, we should consider the impact of current mitigation efforts on the probability and intensity of future natural disasters. For example, protecting one community from flooding may make flooding worse for a downstream community. Finally, it is important to consider the effect of mitigation on development patterns. For example levees may encourage development in a flood plain putting more homes at risk of flooding should the levees fail.

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