Forest Fire/Wildfire Protection

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Summary

Congress continues to face questions about forestry practices, funding levels, and the federal role in wildland fire protection. Recent fire seasons have been, by most standards, among the worst in the past half century. National attention began to focus on wildfires when a prescribed burn in May 2000 escaped control and burned 239 homes in Los Alamos, NM. President Clinton responded by requesting a doubling of wildfire management funds, and Congress enacted much of this proposal in the FY2001 Interior appropriations act (P.L. 106-291). President Bush responded to the severe 2002 fires by proposing a Healthy Forests Initiative to reduce fuel loads by expediting review processes.

Many factors contribute to the threat of wildfire damages. Two major factors are the decline in forest and rangeland health and the expansion of residential areas into wildlands—the wildland-urban interface. Over the past century, aggressive wildfire suppression, as well as past grazing and logging practices, have altered many ecosystems, especially those where light, surface fires were frequent. Many areas now have unnaturally high fuel loads (e.g., dead trees and dense thickets) and an historically unnatural mix of plant species (e.g., exotic invaders).

Fuel treatments have been proposed to reduce the wildfire threats. Prescribed burning—setting fires under specified conditions—can reduce the fine fuels that spread wildfires, but can escape and become catastrophic wildfires, especially if fuel ladders (small trees and dense undergrowth) and wind spread the fire into the forest canopy. Commercial timber harvesting is often proposed, and can reduce heavy fuels and fuel ladders, but exacerbates the threat unless and until the slash (tree tops and limbs) is properly disposed of. Other mechanical treatments (e.g., precommercial thinning, pruning) can reduce fuel ladders, but also temporarily increase fuels on the ground. Treatments can often be more effective if combined (e.g., prescribed burning after thinning). However, some fuel treatments are very expensive, and the benefit of treatments for reducing wildfire threats depend on many factors.

It should also be recognized that, as long as biomass, drought, and high winds exist, catastrophic wildfires will occur. Only about 1% of wildfires become conflagrations, but which fires will "blow up" into crown wildfires is unpredictable. It seems likely that management practices and policies, including fuel treatments, affect the probability of such events. However, past experience with wildfires are of limited value for building predictive models, and research on fire behavior under various circumstances is difficult, at best. Thus, predictive tools for fire protection and control are often based on expert opinion and anecdotes, rather than on research evidence.

Individuals who choose to build homes in the urban-wildland interface face some risk of loss from wildfires, but can take steps to protect their homes. Federal, state, and local governments can and do assist by protecting their own lands, by providing financial and technical assistance, and by providing relief after the fire.

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The spread of housing into forests and other wildlands,[1] combined with various ecosystem health problems, has substantially increased the risks to life and property from wildfire. Wildfires seem more common than in the 1960s and 1970s, with 2005, 2006, and 2007 being the most severe fire seasons since 1960.[2] National attention was focused on the problem by a fire that burned 239 houses in Los Alamos, NM, in May 2000. Issues for Congress include oversight of the agencies' fire management activities and other wildland management practices that have altered fuel loads over time; consideration of programs and processes for reducing fuel loads; and federal roles and responsibilities for wildfire protection and damages. Funding for wildfire protection programs is also a significant congressional issue, but is covered separately in CRS Report RL33990, *Wildfire Funding*, by Ross W. Gorte.

Many discussions of wildfire protection focus on the federal agencies that manage lands and receive funds to prepare for and control wildfires. The Forest Service (FS), in the Department of Agriculture, is the "big brother" among federal wildfire-fighting agencies. The FS is the oldest federal land management agency, created in 1905, with fire control as a principal purpose. The FS administers more land in the 48 coterminous states than any other federal agency, receives about two-thirds of federal fire funding, and created the symbol of fire prevention, Smokey Bear. The Department of the Interior (DOI) contains several land-managing agencies, including the Bureau of Land Management (BLM), National Park Service, Fish and Wildlife Service, and Bureau of Indian Affairs; DOI fire protection programs have been coordinated and funded through the BLM. Despite the substantial attention given to the FS and DOI agencies, the majority of wildlands are privately owned,[3] and states are responsible for fire protection for these lands, as well as for their own lands.

This report provides historical background on wildfires, and describes concerns about the *wildland-urban interface* and about forest and rangeland health.[4] The report discusses fuel management, fire control, and fire effects. The report then examines federal, state, and landowner roles and responsibilities in protecting lands and resources from wildfires, and concludes by discussing current issues for federal wildfire management.

Historical Background

Wildfire has existed in North America for millennia. Many fires were started by lightning, although Native Americans also used fire for various purposes. Wildfires were a problem for early settlers. Major forest fires occurred in New England and the Lake States in the late 1800s,

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[1] Wildlands is a term commonly used for undeveloped areas—forests, grasslands, brush fields, wetlands, deserts, etc. It excludes agricultural lands and pastures, residential areas, and other, relatively intensively developed areas.

[2] National Interagency Fire Center, "Fire Information—Wildland Fire Statistics," available at http://www.nifc.gov/fire_info/fires_acres.htm. Fire season severity is commonly assessed by acres burned, but larger fires may not be "worse" if they burn less intensely, because their damages may be lower. However, fire intensity and damages are not measured for each wildfire, and thus cannot be used to gauge the severity of fire seasons. It is uncertain whether acreage burned might be a reasonable approximation of severity.

[3] In 2003, there were 810.7 million acres of *private* forests and rangelands in the coterminous 48 states. (U.S. Dept. of Agriculture, Natural Resources Conservation Service, *National Resources Inventory: 2003 Annual NRI*, February 2007, p. 5.) This is substantially more than the 386.1 million acres of lands in those 48 states administered by the FS and DOI. (See CRS Report RL32393, *Federal Land Management Agencies: Background on Land and Resources Management*, by Carol Hardy Vincent et al.)

[4] See also CRS Report RS21880, *Wildfire Protection in the Wildland-Urban Interface*, by Ross W. Gorte.

largely fueled by the tree tops and limbs (slash) left after extensive logging. One particularly devastating fire, the Peshtigo, is commonly cited as the worst wildfire in American history; it burned nearly 4 million acres, obliterated a town, and killed 1,500 people in Wisconsin in 1871. Large fires in cut-over areas and the subsequent downstream flooding were principal reasons for Congress authorizing the President in 1891 to establish forest reserves (now national forests).

Federal Fire Policy Evolution

The nascent FS focused strongly on halting wildfires in the national forests following several large fires that burned nearly 5 million acres in Montana and Idaho in 1910. The desire to control wildfires was founded on a belief that fast, aggressive control efforts were efficient, because fires that were stopped while small would not become the large, destructive conflagrations that are so expensive to control. In 1926, the agency developed its *10-acre policy*—that all wildfires should be controlled before they reached 10 acres in size—clearly aimed at keeping wildfires small. Then in 1935, the FS added its *10:00 a.m. policy*—that, for fires exceeding 10 acres, efforts should focus on control before the next burning period began (at 10:00 a.m.). These policies were seen as the most efficient and effective way to control large wildfires.[5]

In the 1970s, these aggressive FS fire control policies began to be questioned. Research had documented that, in some situations, wildfires brought ecological benefits to the burned areas—aiding regeneration of native flora, improving the habitat of native fauna, and reducing infestations of pests and of exotic and invasive species. In recognition of these benefits, the FS and the National Park Service initiated policies titled "prescribed natural fire," colloquially known as "let-burn" policies. Under these policies, fires burning within prescribed areas (such as in wilderness areas) would be monitored, rather than actively suppressed; if weather or other conditions changed or the wildfire threatened to escape the specified area, it would then be suppressed. These policies remained in effect until the 1988 wildfires in the area around Yellowstone National Park. Because at least one of the major fires in Yellowstone began as a prescribed natural fire, the agencies temporarily ended the use of the policy. Today, unplanned fire ignitions (by lightning or humans) that occur within site and weather conditions identified in fire management plans are called wildland fires for resource benefit, and are part of the agencies' fire use programs.[6]

Aggressive fire control policies were abandoned for federal wildfire planning in the late 1970s. The Office of Management and Budget challenged as excessive proposed budget increases based on these policies and a subsequent study suggested that the fire control policies would increase expenditures beyond efficient levels.[7]

Concerns about unnatural fuel loads were raised in the 1990s. Following the 1988 fires in Yellowstone, Congress established the National Commission on Wildfire Disasters, whose 1994

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[5] See Julie K. Gorte and Ross W. Gorte, *Application of Economic Techniques to Fire Management—A Status Review and Evaluation*, USDA Forest Service, Intermountain Research Station, Gen. Tech. Rept. INT-53, Ogden, UT, June 1979.

[6] U.S. Dept. of the Interior and Dept. of Agriculture, *Federal Wildland Fire Management Policy & Program Review: Final Report*, Washington, DC, Dec. 18, 1995. Hereafter referred to as *1995 Federal Wildland Fire Review*.

[7] Stephen J. Pyne, *Fire In America: A Cultural History of Wildland and Rural Fire*, Princeton Univ. Press, Princeton, NJ, 1982, pp. 293-294.

report described a situation of dangerously high fuel accumulations.[8] This report was issued shortly after a major conference examining the health of forest ecosystems in the intermountain west.[9] The summer of 1994 was another severe fire season, leading to more calls for action to prevent future severe fire seasons. The Clinton Administration developed a Western Forest Health Initiative,[10] and organized a review of federal fire policy, because of concerns that federal firefighting resources had been diverted to protecting nearby private residences and communities at a cost to federal lands and resources.[11] In December 1995, the agencies released the new *Federal Wildland Fire Management Policy & Program Review: Final Report*, which altered federal fire policy from priority for private property to equal priority for private property and federal resources, based on values at risk. (Protecting human life remains the first priority in firefighting.)

Concerns about historically unnatural fuel loads and their threat to communities persist. In 1999, the General Accounting Office (GAO; now the Government Accountability Office) issued two reports recommending a cohesive wildfire protection strategy for the FS and a combined strategy for the FS and BLM to address certain firefighting weaknesses.[12] The Clinton Administration developed a program, called the National Fire Plan, and supplemental budget request to respond to the severe 2000 fire season. In the FY2001 Interior appropriations act (P.L. 106-291), Congress enacted the additional funding, and other requirements for the agencies.

During the severe 2002 fire season, the Bush Administration developed a proposal, called the Healthy Forests Initiative, to expedite fuel reduction projects in priority areas. The various elements of the proposal were debated, but none were enacted during the 107th Congress.[13] Some elements have been addressed through regulatory changes, while others were addressed in legislation in the 108th Congress, especially the Healthy Forests Restoration Act of 2003 (P.L. 108-148).[14]

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[8] R. Neil Sampson, chair, *Report of the National Commission on Wildfire Disasters*, Washington, DC, 1994.

[9] See R. Neil Sampson and David L. Adams, eds., *Assessing Forest Ecosystem Health in the Inland West: Papers from the American Forests Workshop, November 14th-20th, 1993, Sun Valley, Idaho*, Food Products Press, New York, NY, 1994. Hereafter cited as *Assessing Forest Ecosystem Health in the Inland West.*

[10] U.S. Dept. of Agriculture, Forest Service, State and Private Forestry, *Western Forest Health Initiative*, Washington, DC, October 31, 1994.

[11] Bob Armstrong, Assistant Secretary for Lands and Minerals Management, U.S. Dept. of the Interior, "Statement," *Fire Policy and Related Forest Health Issues*, joint oversight hearing, House Committees on Resources and on Agriculture, October 4, 1994, U.S. GPO, Washington, DC, 1995, p. 9. Serials No. 103-119 (Committee on Resources) and 103-82 (Committee on Agriculture).

[12] U.S. General Accounting Office, *Western National Forests: A Cohesive Strategy is Needed to Address Catastrophic Wildfire Threats*, GAO/RCED-99-65, Washington, DC, April 1999; and *Federal Wildfire Activities: Current Strategy and Issues Needing Attention*, GAO/RCED-99-233, Washington, DC, August 1999. Hereafter cited as GAO, *Cohesive Strategy Needed*.

[13] See out-of-print CRS Report RL31679, *Wildfire Protection: Legislation in the 107th Congress and Issues in the 108th Congress*, by Ross W. Gorte (available from the author).

[14] For information on recent regulatory and legislative developments on wildfire protection, see CRS Report RL33792, *Federal Lands Managed by the Bureau of Land Management (BLM) and the Forest Service (FS): Issues for the 110th Congress*, by Ross W. Gorte et al.

Efficacy of Fire Protection

FS fire control programs appeared to be quite successful until the 1980s. For example, fewer than 600,000 acres of FS protected land[15] burned each year from 1935 through 1986, after *averaging* 1.2 million acres burned annually during the 1910s. As shown in **Table 1**, the average annual acreage of FS protected land burned declined nearly every decade until the 1970s, but rose substantially in the 1980s and 1990s, concurrent with the shift from fire control to fire management. Furthermore, the acreage of FS protected land burned did not exceed a million acres annually between 1920 and 1986; since then, more than a million acres of FS protected land have burned in each of at least six years—1987, 1988, 1994, 1996, 2000, and 2002. (Statistics on acreage burned by federal agency of jurisdiction have not been available from the National Interagency Fire Center since 2002.) In contrast, the acreage burned of wildlands protected by state or other federal agencies has declined substantially since the 1930s, and has continued at a relatively modest level for the past 40 years, as shown in **Table 1**.

Table 1. Average Annual Acreage Burned by Decade Since 1910

(in acres burned annually)

Decade	Average annual acres burned, FS Protected Lands	Average annual acres burned, Other Lands	Average annual acres burned, Total
1910-1919	1,243,572 acres	not available	not available
1920-1929	616,834 acres	25,387,733 acres	26,004,567 acres
1930-1939	343,013 acres	38,800,182 acres	39,243,195 acres
1940-1949	269,644 acres	22,650,254 acres	22,919,898 acres
1950-1959	261,264 acres	9,154,532 acres	9,415,796 acres
1960-1969	196,221 acres	4,375,034 acres	4,571,255 acres
1970-1979	242,962 acres	2,951,459 acres	3,194,421 acres
1980-1989	488,023 acres	2,494,812 acres	2,982,835 acres
1990-1999	554,577 acres	2,768,981 acres	3,323,558 acres
2000-2008	not available	not available	7,039,236 acres

Sources: U.S. Dept. of Agriculture, *Forest Service Historical Fire Statistics*, unpublished table, Washington, DC; and National Interagency Fire Center, *Fire Information—Wildland Fire Statistics*, at http://www.nifc.gov/fire_info/fires_acres.htm, with FS acres burned deducted. (Pre-1960 data were at the NIFC site on Sept. 20, 2000, but are no longer available.)

There are still occasional severe fire seasons, with more than 6 million acres burned nine times since 1960 and six of those in the past decade—1963, 1969, 1996, 2000, 2002, 2004, 2005, 2006, and 2007.[16] Nonetheless, even the worst of these fire seasons (2006) saw only slightly more acres burned than the annual average in the 1950s.

[15] Under several cooperative agreements, developed to improve protection efficiency, the Forest Service protects some non-federal lands, while other organizations protect some national forest lands; the total acres protected by the Forest Service roughly equals the acres in the National Forest System.

[16] The National Interagency Fire Center has revised the data for 1983-2002, dropping 1988 (the year of the Yellowstone fires) off the list.

It should also be recognized that only a small fraction of wildfires become catastrophic. In one case study, for 1986-1995 in Colorado, less than 1% of all wildfire ignitions grew to more than 1,000 acres, but these larger fires accounted for nearly 79% of the acreage burned.[17] More than 95% of the fires were less than 50 acres, and these 12,608 fires accounted for only 3% of acreage burned. Thus, a small percentage of the fires account for the vast majority of the acres burned, and probably an even larger share of the damages and control costs, since the large fires (conflagrations) burn more intensely than smaller fires and suppression costs (per acre) are higher for conflagrations because of overhead management costs and the substantial cost of aircraft used in fighting conflagrations.

Concerns and Problems

Wildfires stir a primeval fear and fascination in most of us. Many have long been concerned about the loss of valuable timber to fire and about the effects of fire on soils, watersheds, water quality, and wildlife. In addition, the loss of houses and other structures adds to wildfire damages. Historically, wildfires were considered a major threat to people and houses primarily in the brushy hillsides of southern California. However, people have increasingly been building their houses and subdivisions in forests and other wildlands, and this expanding *wildland-urban interface* has increased the wildfire threat to people and houses. Also, a century of using wildlands and suppressing wildfires has apparently significantly increased fuel loads, at least in some ecosystems, and led to historically unnatural combinations of vegetation and structures, exacerbating wildfire threats.[18]

Wildland-Urban Interface (WUI)

The wildland-urban interface has been defined as the area "where combustible homes meet combustible vegetation."[19] This interface includes a wide variety of situations, ranging from individual houses and isolated structures to subdivisions and rural communities surrounded by wildlands. While this situation has always existed to some extent, subdivisions in wildland settings appear to have grown significantly over the past two decades. Standard definitions of the interface have been developed by the federal agencies,[20] but have not been used to assess the changing situation.

Most observers agree that protecting homes and other structures in the interface is an appropriate goal for safeguarding the highest values at risk from wildfire.[21] However, there are differences of opinion about how to best protect the WUI. FS research has indicated that the characteristics of

[17] Leon F. Neuenschwander et al., "Indexing Colorado Watersheds to Risk of Wildfire," *Mapping Wildfire Hazards and Risks*, Food Products Press, New York, NY,2000, pp. 35-55.

[18] R. Neil Sampson et al., "Assessing Forest Ecosystem Health in the Inland West: Overview," *Assessing Forest Ecosystem Health in the Inland West*, pp. 3-10.

[19] *Wildfire Strikes Home! The Report of the National Wildland/Urban Fire Protection Conference*, sponsored by the USDA, Forest Service; the National Fire Protection Association; and the FEMA, U.S. Fire Administration, January 1987, p. 2.

[20] U.S. Dept. of Agriculture and Dept. of the Interior, "Urban Wildland Interface Communities Within the Vicinity of Federal Lands That Are at High Risk From Wildfire," 66 *Federal Register* 751-754, January 4, 2001.

[21] See CRS Report RL34517, *Wildfire Damages to Homes and Resources: Understanding Causes and Reducing Losses*, by Ross W. Gorte

the structures and their immediate surroundings are the primary determinants of whether a structure burns. In particular, non-flammable roofs and cleared vegetation for at least 10 meters (33 feet) and up to 40 meters (130 feet) around the structure is highly likely to protect the structure from wildfire, even when neighboring structures burn.[22] Others propose reducing fuels in a band surrounding communities in the WUI; many proposals for fuel reduction suggest treatments within a half-mile (sometimes a quarter-mile) of WUI communities. Still others suggest that reducing fuels on wildlands removed from the WUI can nonetheless protect communities by reducing the danger of uncontrollable conflagrations.[23] These differences lead to discussions about the proper federal role in protecting homes in the interface (see below).

Forest and Rangeland Health

The increasing extent of wildfires in the national forests in the past two decades has been widely attributed to deteriorating forest and rangeland health, resulting at least in some cases directly from federal forest and rangeland management practices. Ecological conditions in many areas, particularly in the intermountain West (the Rocky Mountains through the Cascades and Sierra Nevadas), have been altered by various activities. Beginning more than a century ago, livestock grazing affected ecosystems by reducing the amount of grass and changing the plant species mix in forests and on rangelands. This reduced the fine fuels that carried surface fires (allowed them to spread), encouraged trees to invade traditionally open grasslands and meadows, and allowed non-native species to become established, all of which, experts believe, induce less frequent but more intense wildfires.[24] In addition, first to support mining and railroad development and later to support the wood products industry, logging of the large pines that characterized many areas has led to regeneration of smaller, less fire-resistant trees in some areas.[25] Roads that provide access for logging, grazing, and recreation have also been implicated in spreading non-native species.[26]

The nature, extent, and severity of these forest and rangeland health problems vary widely, depending on the ecosystem and the history of the site. In rangelands, the problem is likely to be invasion by non-native species (e.g., cheatgrass or spotted knapweed) or by shrubs and small trees (e.g., salt cedar or juniper). In some areas (e.g., western hemlock or inland Douglas-fir stands), the problem may be widespread dead trees due to drought or insect or disease infestations. In others (e.g., southern pines and western mixed conifers), the problem may be dense undergrowth of different plant species (e.g., palmetto in the south and firs in the west). In still others (e.g., ponderosa pine stands) the problem is more likely to be stand stagnation (e.g., too many little green trees, because intra-species competition rarely kills ponderosa pines).

[22] Jack D. Cohen, "Preventing Disaster: Home Ignitability in the Wildland-Urban Interface," *Journal of Forestry*, vol. 102, no. 3 (March 2000), pp. 15-21.

[23] Personal communication, Harv Forsgren, Regional Forester (Region 3), USDA Forest Service in Washington, DC, on Aug. 21, 2003.

[24] W. W. Covington and M. M. Moore, "Postsettlement Changes in Natural Fire Regimes and Forest Structure: Ecological Restoration of Old-Growth Ponderosa Pine Forests," *Assessing Forest Ecosystem Health in the Inland West*, pp. 153-181.

[25] Jay O'Laughlin, "Assessing Forest Health Conditions in Idaho with Forest Inventory Data," *Assessing Forest Ecosystem Health in the Inland West*, pp. 221-247.

[26] Federal Interagency Committee for the Management of Noxious and Exotic Weeds, *Invasive Plants: Changing the Landscape of America*, Washington, DC, 1998, pp. 23-24.

One FS research report has categorized these health problems, for wildfire protection, by classifying ecosystems according to their historical fire regime.[27] The report describes five historical fire regimes:

> I. ecosystems with low-severity, surface fires at least every 35 years (often called *frequent surface-fire* ecosystems);
>
> II. ecosystems with *stand replacement* fires (killing much of the standing vegetation) at least every 35 years;
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> III. ecosystems with mixed severity fires (both surface and stand replacement fires) at 35-100+ year intervals;
>
> IV. ecosystems with stand replacement fires at 35-100+ year intervals; and
>
> V. ecosystems with stand replacement fires at 200+ year intervals.

It is widely recognized that fire suppression has greatly exacerbated these ecological problems, at least in frequent surface-fire ecosystems (fire regime I)—forest ecosystems that evolved with frequent surface fires that burned grasses, needles, and other small fuels at least every 35 years, depending on the site and plant species (e.g., southern yellow pines and ponderosa pine). Surface fires reduce fuel loads by mineralizing biomass that may take decades to rot, and thus provide a flush of nutrients to stimulate new plant growth. Historically, many surface fires were started by lightning, although Native Americans used fires to clear grasslands of encroaching trees, stimulate seed production, and reduce undergrowth and small trees that provide habitat for undesirable insects (e.g., ticks and chiggers) and inhibit mobility and visibility when hunting.[28]

Eliminating frequent surface fires through fire suppression plus other activities has led to unnaturally high fuel loads, by historic standards, in frequent surface-fire ecosystems. These historically unnatural fuel loads can lead to stand replacement fires in ecosystems adapted to frequent surface fires. In particular, small trees and dense undergrowth can create *fuel ladders* that sometimes cause surface fires to spread upward into the forest canopy. In these ecosystems, the frequent surface fires had historically eliminated much of the understory before it got large enough to create fuel ladders. Stand replacement fires in frequent surface-fire ecosystems might regenerate new versions of the original surface-fire adapted ecosystems, but some observers are concerned that these ecosystems might be replaced with a different forest that doesn't contain the big old ponderosa pines and other traditional species of these areas.

Stand replacement fires are not, however, an ecological catastrophe in all ecosystems. Perennial grasses and some tree and brush species have evolved to regenerate following intense fires that kill much of the surface vegetation (fire regimes II, IV, and V). Aspen and some other hardwood tree and brush species, as well as most grasses, regrow from rootstocks that can survive intense wildfires. Some trees, such as jack pine in the Lake States and Canada and lodgepole pine in much of the west, have developed *serotinous* cones, that open and disperse seeds only after

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[27] Kirsten M. Schmidt et al., *Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management*, USDA Forest Service, Rocky Mountain Research Station, Gen. Tech. Rept. RMRS-87, Ft. Collins, CO, April 2002. Hereafter cited as Schmidt et al., *Coarse-Scale Assessment*.

[28] James K. Agee, *Fire Ecology of Pacific Northwest Forests*, Island Press, Washington, DC, 1993, pp. 54-57. Hereafter cited as Agee, *Fire Ecology of PNW Forests*.

exposure to intense heat. In such ecosystems, stand replacement fires are normal and natural, although avoiding the incineration of structures located in those ecosystems is obviously desirable.

Some uncertainty exists over the extent of forest and rangeland health problems and how various management practices can exacerbate or alleviate the problems. In 1995, the FS estimated that 39 million acres in the National Forest System (NFS) were at high risk of catastrophic wildfire, and needed some form of fuel treatment.[29] More recently, the *Coarse-Scale Assessment* reported that 51 million NFS acres were at high risk of significant ecological damage from wildfire, and another 80 million acres were at moderate risk. (See **Table 2**.) The *Coarse-Scale Assessment* also reported 23 million acres of Department of the Interior lands at high risk and 76 million acres at moderate risk. All other lands (calculated as the total shown in the *Coarse-Scale Assessment* less the NFS and DOI lands) included 107 million acres at high risk and 314 million acres at moderate risk of ecological damage.

Fuel Management

Fuel management is a collection of activities intended to reduce the threat of significant damages by wildfires. The FS began its fuel management program in the 1960s. By the late 1970s, earlier agency policies of aggressive suppression of all wildfires had been modified, in recognition of the enormous cost of organizing to achieve this goal and of the ecological benefits that can result from some fires. These understandings have in particular led to an expanded prescribed burning program.

The relatively recent recognition of historically unnatural fuel loads from dead trees, dense understories of trees and other vegetation, and non-native species has spurred additional interest in fuel management activities. The presumption is that lower fuel loads and a lack of fuel ladders will reduce the extent of wildfires, the damages they cause, and the cost of controlling them. Numerous on-the-ground examples support this belief. However, little empirical research has documented this presumption. As noted in one research study, “scant information exists on fuel treatment efficacy for reducing wildfire severity.”[30] This study also found that “fuel treatments moderate extreme fire behavior within treated areas, at least in” frequent surface-fire ecosystems. Others have found different results elsewhere; one study reported “no evidence that prescribed burning in these [southern California] brushlands provides any resource benefit ... in this crown-fire ecosystem.”[31] A recent summary of wildfire research reported that prescribed burning generally reduced fire severity, that mechanical fuel reduction did not consistently reduce fire severity, and that little research has examined the potential impacts of mechanical fuel reduction with prescribed burning or of commercial logging.[32]

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[29] Enoch Bell et al., *Fire Economics Assessment Report*, unpublished report submitted to USDA Forest Service, Fire and Aviation Management, on Sept. 1, 1995.

[30] Philip N. Omi and Erik J. Martinson, *Effects of Fuels Treatment on Wildfire Severity: Final Report*, submitted to the Joint Fire Science Program Governing Board, Colorado State Univ., Western Forest Fire Research Center, Ft. Collins, CO, March 25, 2002, p. i.

[31] Jon E. Keeley, “Fire Management of California Shrubland Landscapes,” *Environmental Management*, vol. 29, no. 3 (2002), pp. 395-408.

[32] Henry Carey and Martha Schumann, *Modifying WildFire Behavior—The Effectiveness of Fuel Treatments: The Status of Out Knowledge*, Southwest Region Working Paper 2, National Community Forestry Center, Santa Fe, NM, (continued...)

Table 2. Lands at Risk of Ecological Change, by Historic Fire Regime

(in millions of acres)

Risk of Ecological Damage	Regime I 0-35 years; surface fire	Regime II 0-35 years; crown fire	Regime III 35-100+; mixed fire	Regime IV 35-100+; crown fire	Regime V 200+ yrs; crown fire	Total
National Forest System lands						
Class 1: low	19.87	4.46	16.05	5.26	19.31	64.95
Class 2: mod.	34.96	8.66	26.71	7.35	2.76	80.45
Class 3: high	28.83	0.36	11.17	10.49	0.27	51.12
NFS Total	*83.67*	*13.48*	*53.93*	*23.11*	*22.35*	*196.52*
Department of the Interior lands						
Class 1: low	18.70	19.47	62.05	23.98	4.23	128.42
Class 2: mod.	23.83	22.87	25.82	2.93	0.38	75.83
Class 3: high	6.46	0.37	9.92	6.61	0.12	23.47
DOI Total	*49.00*	*42.70*	*97.80*	*33.51*	*4.72*	*227.72*
Private, state, and other federal lands						
Class 1: low	136.46	168.62	49.55	23.83	25.02	404.60
Class 2: mod.	117.37	101.66	59.72	25.06	10.57	313.54
Class 3: high	42.20	9.62	32.92	17.93	4.51	107.18
Other Total	*296.02*	*279.89*	*142.18*	*66.81*	*40.10*	*825.01*

Source: Schmidt et al., *Coarse-Scale Assessment*, pp. 13-15.

Before examining fuel management tools, a brief description of fuels may be helpful.[33] Wildfires are typically spread by fine fuels[34]—needles, leaves, grass, etc.—both on the surface and in the tree crowns (in a stand-replacement crown fire); these are known as 1-hour time lag fuels, because they dry out (lose two-thirds of their moisture content) in about an hour. Small fuels, known as 10-hour time lag fuels, are woody twigs and branches, up to a quarter-inch in diameter; these fuels also help spread wildfires because they ignite and burn quickly. Larger fuels—particularly the 1000-hour time lag fuels (more than 3 inches in diameter)—may contribute to the intensity and thus to the damage fires cause, but contribute little to the rate of spread, because they are slow to ignite. One researcher noted that only 5% of large tree stems and 10% of tree branches were consumed in high intensity fires, while 100% of the foliage and 75% of the understory vegetation were consumed.[35] Finally, *ladders* of fine and small fuels between the

(...continued)

April 2003.

[33] See Arthur A. Brown and Kenneth P. Davis, "Chapter 4: Forest Fuels," *Forest Fire Control and Use*, McGraw-Hill Book Co., New York, NY, 1973, pp. 79-110. Hereafter cited as Brown and Davis, *Fire Control and Use*.

[34] Robert E. Martin and Arthur P. Brackebusch, "Fire Hazard and Conflagration Prevention," *Environmental Effects of Forest Residues Management in the Pacific Northwest: A State-of-Knowledge Compendium,* USDA Forest Service, Pacific Northwest Research Station, Gen. Tech. Rept. PNW-24, Portland, OR, 1974.

[35] Agee, *Fire Ecology of PNW Forests*, p. 42. It is also important to recognize that the percentage of biomass in 1-hour, 10-hour, 100-hour, and 1000-hour fuels depends largely on tree diameter, with the percentage in large fuels increasing as diameter increases.

surface and the tree crowns can spread surface fires into the canopy, thus turning a surface fire into a stand-replacement fire.

Prescribed Burning

Fire has been used as a tool for a long time.[36] Native Americans lit fires for various purposes, such as to reduce brush and stimulate grass growth. Settlers used fires to clear woody debris in creating agricultural fields. In forestry, fire has been used to eliminate logging debris, by burning brush piles and by prescribed burning harvested sites to prepare them for reforestation.[37]

Prescribed burning has been used increasingly over the past 40 years to reduce fuel loads on federal lands. FS prescribed burning has averaged 1.6 million acres annually over the past five years. BLM prescribed burning has averaged nearly 1.2 million acres annually since FY2003. These burning programs are a significant increase from historic levels; as recently as FY1995, the acreage in prescribed burns was 541,300 FS acres and 57,000 BLM acres. However, much of FS prescribed burning is in the FS Southern Region; prescribed burning in the intermountain west is still at relatively modest levels.

Typically, areas to be burned are identified in agency plans, and fire lines (essentially dirt paths) are created around the perimeter. The fires are lit when the weather conditions permit (i.e., when the *burning prescription* is fulfilled)—when the humidity is low enough to get the fuels to burn, but not when the humidity is so low or wind speed so high that the burning cannot be contained. (This, of course, presumes accurate knowledge of existing and expected weather and wind conditions, as well as sufficient fire control crews with adequate training on the site.) When the fire reaches the perimeter limits, the crews “mop up” the burn area to assure that no hot embers remain to start a wildfire after everyone is gone.

Prescribed burning is widely used for fuel management because it reduces biomass (the fuels) to ashes (minerals). It is particularly effective at reducing the smaller fuels, especially in the arid west where deterioration by decomposers (insects, fungi, etc.) is often very slow. In fact, it is the only human treatment that directly reduces the fine and small fuels that are important in spreading wildfires. However, prescribed fires are not particularly effective at reducing larger-diameter fuels or thinning stands to desired densities and diameters.[38]

There are several limitations in using prescribed fire. The most obvious is that prescribed fires can be risky—fire is not a *controlled* tool; rather, it is a self-sustaining chemical reaction that, once ignited, continues until the fuel supply is exhausted.[39] Fire control (for both wildfires and prescribed fires) thus focuses on removing the continuous fuel supply by creating a fire line dug

[36] Historical evidence indicates that current levels of burning through prescribed burns and wildfires represent levels perhaps 10%-30% of pre-industrial burning levels from natural and Native-set fires. See Bill Leenhouts, “Assessment of Biomass Burning in the Conterminous United States,” *Conservation Ecology* 2(1), 1998, available on Jan. 16, 2007, at http://www.ecologyandsociety.org/vol2/iss1/art1/. Hereafter cited as Leenhouts, *Assessment of Biomass Burning*.

[37] David M. Smith et al., *The Practice of Silviculture: Applied Forest Ecology*, John Wiley & Sons, New York, NY, 1997. Hereafter cited as Smith et al., *The Practice of Silviculture*.

[38] See Brown and Davis, *Fire Control and Use*, pp. 560-572.

[39] Fire can also be halted by eliminating the supply of oxygen, as occurs when fire retardant (“slurry”) is spread on forest fires from airplanes (“slurry bombers”). However, reducing oxygen supply usually can only occur in a limited area, because of the cost to spread the fire retardant.

down to mineral soil. The line must be wide enough to prevent the spread of fire by radiation (i.e., the heat from the flames must decline sufficiently across the space that the biomass outside the fire line does not reach combustion temperature, about 550^{o} F). Minor variations in wind and in fuel loads adjacent to the fire line can lead to fires jumping the fire line, causing the fire to escape from control. Winds can also lift burning embers across fire lines, causing spot fires outside the fire line which can grow into major wildfires under certain conditions (such as occurred near Los Alamos, NM, in May 2000). Even when general weather conditions—temperature, humidity, and especially winds—are within the limits identified for prescribed fires, localized variations in the site (e.g., slope, aspect,[40] and fuel load) and in weather (e.g., humidity and wind) can be problematic. Thus, prescribed fires inherently carry some degree of risk, especially in ecosystems adapted to stand-replacement fires and in areas where the understory and undergrowth have created fuel ladders.

Another concern is that prescribed fires generate substantial quantities of smoke—air pollution with high concentrations of carbon monoxide, hydrocarbons, and especially particulates that degrade visibility. Some assert that prescribed fires merely shift the timing of air pollution from wildfires. Others note that smoke from pre-industrial wildland fires was at least three times more than from current levels from prescribed burning and wildfire.[41] Others have observed that fire prescriptions are typically cooler and more humid than wildfire burning conditions, and thus prescribed fires may produce more pollution (because of less efficient burning) than wildfires burning the same area. The Clean Air Act requires regulations to preserve air quality, and regulations governing particulate emissions and regional haze have been of concern to land managers who want to expand prescribed burning programs. Previous proposed legislation (e.g., H.R. 236, 106th Congress) would have exempted FS prescribed burning from air quality regulations for 10 years, to demonstrate that an aggressive prescribed burning program will reduce total particulate emissions from prescribed burning and wildfires. However, owners and operators of other particulate emitters (e.g., diesel vehicles and fossil fuel power plants) generally object to such exemptions, arguing that their emissions would likely be regulated more stringently, even though wildland fires are one of the largest sources of particulates.[42]

Salvage and Other Timber Harvesting

Another tool commonly proposed for fuel treatment is traditional timber harvesting, including salvaging dead and dying trees before they rot or succumb to disease and commercially thinning dense stands. In areas where the forest health problems include large numbers of dead and dying trees, a shift toward an inappropriate or undesirable tree species mix, or a dense understory of commercially usable trees, timber harvesting can be used to improve forest health and remove woody biomass from the forest. Nonetheless, some interest groups object to using salvage and other timber harvests to improve forest health.[43]

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[40] Aspect is the direction which the slope is facing; in the northern hemisphere, south-facing slopes (south aspects) get more radiant energy from the sun than north aspects, and thus are inherently warmer and drier, and hence are at greater risk of more intense wildfires.

[41] Leenhouts, *Assessment of Biomass Burning*.

[42] See, for example, U.S. House, Committee on Resources, *Hearing on the Use of Fire as a Management Tool and Its Risks and Benefits for Forest Health and Air Quality*, Sept. 30, 1997, Serial No. 105-45, GPO, Washington, DC, 141 p.

[43] Timber harvesting has a variety of proponents and opponents for reasons beyond fuel management. Some interests object to timber harvesting on a variety of grounds, including the poor financial performance of FS timber sales and the degradation of water quality and certain wildlife habitats that follows some timber harvesting. Others defend timber (continued...)

Timber generally may only be removed from federal forests under timber sale contracts. Stewardship contracts allow timber sales and forest management services, such as fuel reduction, to be combined in one contract, essentially as a trade of goods (timber) for services (fuel reduction); this form of contracting is discussed below, under "Other Fuel Management Tools." Because timber sale contracts have to be bought and goods-for-services contracts must generate value to provide services, the contracts generally include the removal of large, merchantable trees. Critics argue that the need for merchantable products compromises reducing fuel loads and achieving desired forest conditions.

Timber harvests remove heavy fuels that contribute to fire intensity, and can break fuel ladders, but the remaining limbs and tree tops ("slash") substantially increase fuel loads on the ground and get in the way of controlling future fires, at least in the short term, until the slash is removed or disposed of through burning. "Slash is a fire hazard mainly because it represents an unusually large volume of fuel distributed in such a way that it is a dangerous impediment in the construction of fire lines" (i.e., in suppressing fires).[44]

If logging slash is treated, as has long been a standard practice following timber harvesting, the increased fire danger from higher fuel loads that follow timber harvesting can be ameliorated. Various slash treatments are used to reduce the fire hazard, including lop-and-scatter, pile-and-burn, and chipping.[45] Lop-and-scatter consists of cutting the tops and limbs so that they lie close to the ground, thereby hastening decomposition and possibly preparing the material for broadcast burning (essentially, prescribed burning of the timber harvest site). Pile-and-burn is exactly that, piling the slash (by hand or more typically by bulldozer) and burning the piles when conditions are appropriate (dry enough, but not too dry, and with little or no wind). Chipping is feeding the slash through a chipper, a machine that reduces the slash to particles about the size of a silver dollar. and scattering the chips to allow them to decompose. Thorough slash disposal can significantly reduce fuel loads, particularly on sites with large amounts of noncommercial biomass (e.g., undergrowth and unusable tree species) and if combined with some type of prescribed burning. However, data on the actual extent of various slash disposal methods and on needed slash disposal appear to be available only for a few areas.

Other Fuel Management Tools

The other principal tool for fuel management is mechanical treatment of the fuels.[46] One common method is precommercial thinning—cutting down many of the small (less than 4½-inch diameter) trees that have little or no current market value. Other treatments include pruning and mechanical release of seedlings (principally by cutting down or mowing competing vegetation). Mechanical treatments are often effective at eliminating fuel ladders, but as with timber cutting, do not reduce

(...continued)

sales for the employment and income provided in isolated, resource-dependent communities as well as for increasing water yields and available habitat for other wildlife species. The arguments supporting and opposing timber harvests generally have often been raised in discussions about fire protection, but are not reproduced in this report. See CRS Report 95-364, *Salvage Timber Sales and Forest Health*, by Ross W. Gorte (out-of-print; available from the author).

[44] Smith et al., *The Practice of Silviculture*.

[45] Ibid.

[46] Chemical treatments (herbicides) are also used in forestry, mostly on unwanted vegetation, but they are not included here as a fuel treatment tool, because they are used primarily to kill live biomass rather than to reduce biomass levels on a site. Biological treatments (e.g., using goats to eat the small diameter material) are feasible, but are rarely used.

the fine fuels on the sites without additional treatment (e.g., without prescribed burning). Mechanical fuel treatments alone tend to increase fine fuels and sometimes larger fuels on the ground in the short term, until the slash has been treated.

Some critics have suggested using traditionally unused biomass, such as slash and thinning debris, in new industrial ways, such as using the wood for paper or particleboard or burning the biomass to generate electricity.[47] Research has indicated that harvesting small diameter timber may be economically feasible,[48] and one study reported net revenues of $624 per acre for comprehensive fuel reduction treatments in Montana that included removal and sale of merchantable wood.[49] However, thus far, collecting and hauling chipped slash and other biomass for products or energy have apparently not been seen as economically viable by potential timber purchasers, given that such woody materials are currently left on the harvest sites.[50]

Another possibility is to significantly change the traditional approach to timber sales. Stewardship contracting, in various forms, has been tested in various national forests.[51] Sometimes, the stewardship contract (payment and performance) is based on the condition of the stand after the treatment, rather than on the volume harvested; this is also known as end-results contracting. A variation on this theme, which has been discussed sporadically for more than 30 years, is to separate the forest treatment from the sale of the wood. The most common form is essentially to use commercial timber to pay for other treatments; that is, the contractor removes the specified commercial timber and is required to perform other activities, such as precommercial thinning of a specified area. Because of the implicit trade of timber for other activities, this is often called goods-for-services stewardship contracting. FS and BLM goods-for-services stewardship contracting was authorized through FY2013 in the FY2003 Continuing Appropriations Resolution (P.L. 108-7). Some observers believe that such alternative approaches could lead to development of an industry based on small diameter wood, and thus significantly reduce the cost of fuel management. Others fear that this could create an industry that cannot be sustained after the current excess biomass has been removed or that would need continuing subsidies.

Fuel Management Funding

Direct federal funding for prescribed burning and other fuel treatments (typically called *hazardous fuels* or *fuel management*) is part of FS and BLM appropriations for Wildfire Management. (See CRS Report RL33990, *Wildfire Funding*, by Ross W. Gorte.) Appropriations for fuel reduction have risen from less than $100 million in FY1999 to more than $400 million annually since FY2003, and to $775 million in FY2008, with emergency supplemental funding.

[47] Robert Nelson, University of Maryland, cited in: Rocky Barker, "Wildfires Creating Odd Bedfellows," *The Idaho Statesman*, Aug. 14, 2000, pp. 1A, 7A.

[48] Henry Spelter, Ron Wang, and Peter Ince, *Economic Feasibility of Products From Inland West Small Diameter Timber*, USDA Forest Service, Forest Products Lab, FPL-GTR-92, Madison, WI, May 1996, 17 p.

[49] Carl E. Fieldler, Charles E. Keegan, Todd A. Morgan, and Christopher W. Woodall, "Fire Hazard and Potential Treatment Effectiveness: A Statewide Assessment in Montana," *Journal of Forestry*, vol. 101, no. 2 (March 2003), p. 7.

[50] Research documenting the economics of slash use (in contrast to small diameter trees) is lacking. However, this seems a reasonable conclusion, given that the slash is left on the site by the timber purchaser (who could remove and sell the material) and that the agencies and various interest groups have been trying to develop alternatives to the traditional contracts (e.g., stewardship contracts) to remove thinning slash and other biomass fuels.

[51] See CRS Report RS20985, *Stewardship Contracting for Federal Forests*, by Ross W. Gorte.

Funds appropriated for other purposes can also provide fuel treatment benefits. As noted above, salvage and other commercial timber sales can be used to reduce fuels in some circumstances. Various accounts, both annual appropriations and mandatory spending, provide funding for reforestation, timber stand improvement, and other activities. Reforestation actually increases fuels, but timber stand improvement includes precommercial thinning, pruning, and other mechanical vegetative treatments included in "Other Fuel Management Tools" (see above), as well as herbicide use and other treatments that do not reduce fuels.

Fire Control

Wildfire Management Funding

The cost of federal fire management is high and has risen significantly from historic levels. Wildfire appropriations for the FS and DOI totaled less than $1 billion annually prior to FY1997. For FY2003-FY2008, funding averaged more than $3 billion annually. (See CRS Report RL33990, *Wildfire Funding*, by Ross W. Gorte.) One critic has observed that emergency supplemental appropriations, to replenish funds borrowed from other accounts to pay for firefighting, are viewed by agency employees as "free money" and has suggested that this has led to wasting federal firefighting funds, which he calls "fire boondoggles."[52] Another critic asserts that poorly designed incentives are the principal cause of the current problems and that the current fire management funding system will not resolve those problems.[53]

Over the past five years, the FS has received about 70% of the funds appropriated by Congress for wildfire preparedness and operations (including emergency supplemental funds). The other 30% goes to the BLM, which coordinates wildfire management funding for the DOI land managing agencies (BLM, the National Park Service, U.S. Fish and Wildlife Service, and Bureau of Indian Affairs); the BLM has retained about 60% of DOI funding for its wildfire activities.

Fire Control Policies and Practices

Federal fire management policy was revised in 1995, after severe fires in 1994 and the deaths of several firefighters. Current federal wildfire policy is to protect human life first, and then to protect property and natural resources from wildfires.[54] This policy includes viewing fire as a natural process in ecosystems where and when fires can be allowed to burn with reasonable safety. But when wildfires threaten life, property, and resources, the agencies act to suppress those fires.

Despite control efforts, some wildfires clearly become the kind of conflagration (stand replacement fire or crown fire) that gets media attention. As noted above, relatively few wildfires become conflagrations; it is unknown how many wildfires might become conflagrations in the absence of fire suppression efforts.

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[52] Robert H. Nelson, *A Burning Issue: A Case for Abolishing the U.S. Forest Service*, Rowman & Littlefield Publishers, Inc., Lanham, MD, 2000, pp. 15-43. Hereafter cited as Nelson, *A Burning Issue*.

[53] Randal O'Toole, *Reforming the Fire Service: An Analysis of Federal Fire Budgets and Incentives*, Thoreau Institute, Bandon, OR, July 2002. Hereafter cited as O'Toole, *Reforming the Fire Service*.

[54] *1995 Federal Wildland Fire Review*.

A wide array of factors determine whether a wildfire will blow up into a conflagration. Some factors are inherent in the site: slope (fires burn faster up steep slopes); aspect (south-facing slopes are warmer and drier than north-facing slopes); and ecology (some plant species are adapted to periodic stand replacement fires). Other factors are transient, changing over time (from hours to years): moisture levels (current and recent humidity; long-term drought); wind (ranging from gentle breezes to gale force winds in some thunderstorms); and fuel load and spatial distribution (more biomass and fuel ladders make conflagrations more likely).

Whether a wildfire becomes a conflagration can also be influenced by land management practices and policies. Historic grazing and logging practices (by encouraging growth of many small trees), and especially fire suppression over the past century, appear to have contributed to unprecedented fuel loads in some ecosystems. Fuel treatments can reduce fuel loads, and thus probably reduce the likelihood and severity of catastrophic wildfires, at least in some ecosystems; however, some policies and decisions may restrict fuel treatment—for example, air quality protection that limits prescribed burning or wilderness designation that prevents fuel reduction with motorized or mechanical equipment. Other practices and policies are more problematic. For example, timber harvesting can reduce fuel loads, if accompanied by effective slash disposal, but data on the need for and on the extent and efficacy of slash disposal are not available. Similarly, road construction into previously unroaded areas can increase access, and thus facilitate fuel treatment and fire suppression; conversely, roadless area protection and even road obliteration[55] can impede fuel treatment, but may reduce the likelihood of a wildfire ignition, because human-caused wildfires are more common along roads.

Once a wildfire becomes a conflagration, halting its spread is exceedingly difficult, if not impossible. Dropping water or fire retardant ("slurry") from helicopters or airplanes ("slurry bombers") can occasionally return a crown fire to the surface, where firefighters can control it, and can be used to protect individually valuable sites (e.g., structures). However, this strategy is not particularly useful in large, extended fires.[56] Setting backfires—lighting fires from a fire line to burn toward the conflagration—can eliminate the fuel ahead of the conflagration, thus halting its spread, but can be dangerous, because the backfire sometimes becomes part of the conflagration. Most firefighters recognize the futility of some firefighting efforts, acknowledging that some conflagrations will burn until they run out of fuel (move into an ecosystem or an area where the fuel is insufficient to support the conflagration) or the weather changes (the wind dies or precipitation begins, or both).

Wildfire Effects

Wildfires cause damages, killing some plants and occasionally animals.[57] Firefighters have been injured and killed, and structures can be damaged or destroyed. The loss of plants can heighten the risk of significant erosion and landslides. Some observers have reported "soil glassification,"

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[55] Road obliteration is closing the road and returning the roadbed to near-natural conditions.

[56] *Federal Aerial Firefighting: Assessing Safety and Effectiveness*, Blue Ribbon Panel Report to the Chief, USDA Forest Service and Director, USDI Bureau of Land Management, available at http://www.wildfirelessons.net/documents/BRP_Final12052002.pdf.

[57] For a thorough discussion of these effects, see L. Jack Lyon et al., *Wildland Fire in Ecosystems: Effects of Fire on Fauna*, USDA Forest Service, Rocky Mountain Research Station, Gen. Tech. Rept. RMRS-GTR-42-vol. 1,Ogden, UT, Jan. 2000. Hereafter cited as Lyon, et al., *Effects of Fire on Fauna*.

where the silica in the soils has been melted and fused, forming an impermeable layer in the soil; however, research has yet to document the extent, frequency, and duration of this condition, and the soils and burning conditions under which it occurs. Others have noted that "even the most intense forest fire will rarely have a direct heating effect on the soil at depths below 7 to 10 cm" (centimeters), about 3 to 4 inches.[58]

Damages are almost certainly greater from stand replacement fires than from surface fires. Stand replacement fires burn more fuel, and thus burn hotter (more intensely) than surface fires. Stand replacement fires kill many plants in the burned area, making natural recovery slower and increasing the potential for erosion and landslides. Also, because they burn hotter, stand replacement fires generally are more difficult to suppress, raising risks to firefighters and to structures. Finally, stand replacement fires generate substantial quantities of smoke, which can directly affect people's health and well-being.

Wildfires, especially conflagrations, can also have significant local economic effects, both short-term and long-term, with larger fires generally having greater and longer-term impacts. Wildfires, and even extreme fire danger, may directly curtail recreation and tourism in and near the fires.[59] If an area's aesthetics are impaired, local property values can decline. Extensive fire damage to trees can significantly alter the timber supply, both through a short-term glut from timber salvage and a longer-term decline while the trees regrow. Water supplies can be degraded by post-fire erosion and stream sedimentation, but the volume flowing from the burned area may increase. However, federal wildfire management includes substantial expenditures, and fire-fighting jobs are considered financially desirable in many areas.[60]

Ecological damages from fires are more difficult to determine, and may well be overstated, for two reasons. First, burned areas look devastated immediately following the fire, even when recovery is likely; for example, conifers with as much as 60% of the crown scorched are likely to survive.[61] Second, even the most intense stand replacement fires do not burn 100% of the biomass within the burn's perimeter—fires are patchy. For example, in the 1988 fires in Yellowstone, nearly 30% of the area within the fire perimeters was unburned, and another 15%-20% burned lightly (a surface fire); 50%-55% of the area burned as a stand replacement fire.[62]

Emergency rehabilitation is common following large fires. This is typically justified by the need for controlling erosion and preventing landslides, and may be particularly important for fire lines (dug to mineral soil) that go up steep slopes and could become gullies or ravines without treatment. Sometimes, the rehabilitation includes salvaging dead and damaged trees, because the wood's quality and value deteriorate following the fire. Emergency rehabilitation often involves seeding the sites with fast-growing grasses. While helpful for erosion control, such efforts might inhibit natural restoration if the grasses are not native species or if they inhibit tree seed germination or seedling survival.

[58] Craig Chandler et al., *Fire In Forestry. Volume I: Forest Fire Behavior and Effects*, John Wiley & Sons, New York, NY, 1983, p. 173.

[59] Paul E. Polzin, Michael S. Yuan, and Ervin G. Schuster, *Some Economic Impacts of the 1988 Fires in the Yellowstone Area*, USDA Forest Service, Intermountain Research Station, Research Note INT-418, Ogden, UT, October 1993.

[60] Nelson, *A Burning Issue*, pp. 37-38.

[61] See Ross W. Gorte, *Fire Effects Appraisal: The Wisconsin DNR Example*, Michigan State Univ., Ph.D. dissertation, East Lansing, MI, June 1981.

[62] See Lyon, et al., *Effects of Fire on Fauna*, p. 44.

Finally, as mentioned above, wildfires can also generate ecological benefits. Many plants regrow quickly following wildfires, because fire converts organic matter to available mineral nutrients. Some plant species, such as aspen and especially many native perennial grasses, also regrow from root systems that are rarely damaged by wildfire. Other plant species, such as lodgepole pine and jack pine, have evolved to depend on stand replacement fires for their regeneration; fire is *necessary* to open their cones and spread their seeds. One author identified research reporting various significant ecosystems threatened by *fire exclusion*—including aspen, whitebark pine, and ponderosa pine (western montane ecosystems), longleaf pine, pitch pine, and oak savannah (southern and eastern ecosystems), and the tallgrass prairie.[63] Other researchers found that, of the 146 rare, threatened, or endangered plants in the coterminous 48 states for which there is conclusive information on fire effects, 135 species (92%) benefit from fire or are found in fire-adapted ecosystems.[64]

Animals, as well as plants, can benefit from fire. Some individual animals may be killed, especially by catastrophic fires, but populations and communities are rarely threatened. Many species are attracted to burned areas following fires—some even during or immediately after the fire. Species can be attracted by the newly available minerals or the reduced vegetation allowing them to see and catch prey. Others are attracted in the weeks to months (even years) following, to the new plant growth (including fresh and available seeds and berries), for insects and other prey, or for habitat (e.g., snags for woodpeckers and other cavity nesters). A few may be highly dependent on fire; the endangered Kirtland's warbler, for example, only nests under young jack pine that was regenerated by fire, because only fire-regenerated jack pine stands are dense enough to protect the nestlings from predators.

In summary, many of the ecological benefits of wildfire that have become more widely recognized over the past 30 years are generally associated with light surface fires in frequent-fire ecosystems. This is clearly one of the justifications given for fuel treatments. Damage is likely to be greater from stand replacement fires, especially in frequent-fire ecosystems, but even crown fires produce benefits in some situations (e.g., for the jack pine regeneration needed for successful Kirtland's warbler nesting).

Roles and Responsibilities

Landowner Responsibilities

Individuals who choose to build or live in homes and other structures in the wildland-urban interface face some risk of loss from wildfires. As noted above, catastrophic fires occur, despite our best efforts, and can threaten houses and other buildings. To date, insurance companies (and state insurance regulators) have done relatively little to ameliorate these risks, in part because of federal disaster assistance paid whenever numerous homes are burned (such as in Los Alamos in May 2000). However, landowners can take steps, individually and collectively, to reduce the threat to their structures.

[63] Leenhouts, *Assessment of Biomass Burning*.

[64] Amy Hessl and Susan Spackman, *Effects of Fire on Threatened and Endangered Plants: An Annotated Bibliography*, U.S. Dept. of the Interior, National Biological Service, Information and Technical Report 2, Fort Collins, CO, n.d.

Research has documented that *home ignitability*—the likelihood of a house catching fire and burning down—depends substantially on the characteristics of the structure and its immediate surroundings.[65] Flammable exteriors—wood siding and especially flammable roofs—increase the chances that a structure will ignite by radiation (heat from the surrounding burning forest) or from firebrands (burning materials carried aloft by wind or convection and falling ahead of the fire). Alternate materials (e.g., brick or aluminum siding and slate or copper roofing) and protective treatments can reduce the risk. In addition, the probability of a home igniting by radiation depends on its distance from the flames. Researchers found that 85%-95% of structures with nonflammable roofs survived two major California fires (in 1961 and 1990) when there were clearances of 10 meters (33 feet) or more between the homes and surrounding vegetation.[66] Thus, building with fire resistant materials and clearing flammable materials—including vegetation, firewood piles, and untreated wood decks—from around structures reduces their chances of burning.

In addition, landowners can cooperate in protecting their homes in the wildland-urban interface. Fuel reduction within and around such subdivisions can reduce the risk, and economies of scale suggest that treatment costs for a subdivision might be lower than for an individual (especially if volunteer labor is contributed). In addition, as noted above, narrow and unmarked roads can hinder fire crews from reaching wildfires. Assuring adequate roads that are clearly marked and mapped can help firefighters to protect subdivisions. Finally, communal water sources, such as ponds and cisterns, may improve the protection of structures and subdivisions.

State and Local Government Roles and Responsibilities

In general, the states are responsible for fire protection on non-federal lands, although cooperative agreements with the federal agencies may shift those responsibilities. Typically, local governments are responsible for putting out structure fires. Maintaining some separation between suppressing structural fires and wildfires may be appropriate, because the suppression techniques and firefighter hazards and training differ substantially. Nonetheless, cooperation and some overlapping responsibilities are also warranted, simply because of the locations of federal, state, and local firefighting forces.

In addition, state and local governments have other responsibilities that affect wildfire threats to homes. For example, zoning codes—what can be built where—and building codes—permissible construction standards and materials—are typically regulated locally. These codes could (and some undoubtedly do) include restrictions, standards, or guidelines for improving fire protection in the wildland-urban interface.

The insurance industry, and home fire insurance requirements, are generally regulated by states. State regulators could work with the industry to increase the consideration of wildfire protection and home defensibility in homeowners' insurance. Road construction and road maintenance are often both state and local responsibilities, depending on the road; these roads are usually designed and identified in ways that are useful for fire suppression crews. State and local governments

[65] See Jack D. Cohen, "Reducing the Wildland Fire Threat to Homes: Where and How Much?" *Proceedings of the Symposium on Fire Economics, Planning, and Policy: Bottom Lines* (San Diego, CA: April 5-9, 1999), USDA Forest Service, Pacific Southwest Research Station, Gen. Tech. Rept. PSW-GTR-173, Berkeley, CA, Dec. 1999, pp. 189-195. Hereafter cited as Cohen, *Reducing the Wildland Fire Threat to Homes.*

[66] Ibid.

could further assist home protection from wildfires by supporting programs to inform residents, especially those in the urban-wildland interface, of ways that they can protect their homes.

Federal Roles and Responsibilities

The federal government has several roles in protecting lands and resources from wildfire, including protecting federal lands, assisting protection by states and local governments, and assisting public and private landowners in the aftermath of a disaster. These programs and their funding levels are described in CRS Report RL33990, *Wildfire Funding*, and CRS Report RL31065, *Forestry Assistance Programs*, both by Ross W. Gorte.

Federal Land Protection

The federal government clearly is responsible for fire protection on federal lands. Federal responsibility to protect neighboring non-federal lands, resources, and structures, however, is less clear. This issue was raised following several 1994 fires, where the federal officials observed that firefighting resources were diverted to protecting nearby private residences and communities at a cost to federal lands and resources.[67] In December 1995, the agencies released the new *Federal Wildland Fire Management Policy & Program Review: Final Report,* which altered federal fire policy from priority for private property to equal priority for private property and federal resources, based on values at risk. (Protecting human life is the first priority in firefighting.) Funding for fire protection of federal lands accounts for about 95% of all federal wildfire management appropriations. As noted above, fire appropriations have risen dramatically over the past decade.

Cooperative Assistance

The federal government also provides assistance for fire protection. Most federal wildfire protection assistance has been through the FS, but the Federal Emergency Management Agency (FEMA) in the Department of Homeland Security also has a program to assist in protecting communities from disasters (including wildfire).

FS efforts are operated through a cooperative fire protection program within the State and Private Forestry (S&PF) branch. This fire program includes financial and technical assistance to states and to volunteer fire departments. The funding provides a nationwide fire prevention program and equipment acquisition and transfer (the Federal Excess Personal Property program) as well as training and other help for state and local fire organizations. The 2002 Farm Bill (P.L. 107-171) created a new community fire protection program under which the FS can assist communities in fuel reduction and other activities on private lands in the wildland-urban interface. One particular program, FIREWISE, is supported through an agreement with and grant to the National Fire Protection Association, in conjunction with the National Association of State Foresters, to help private landowners learn how to protect their property from catastrophic wildfire.

[67] See footnote 11.

Funding for cooperative fire assistance rose substantially in FY2001, from less than $30 million to nearly $150 million. Funding has declined since, but remains substantially higher than the $15-$20 million annually in the 1990s.

FEMA has programs to assist fire protection efforts.[68] One FEMA program is fire suppression grants under the Stafford Act (the Disaster Relief and Emergency Assistance Act, 42 U.S.C. §5187). These are grants to states to assist in suppressing wildfires that threaten to become major disasters. Also, the U.S. Fire Administration is a FEMA entity charged with reducing deaths, injuries, and property losses from fires; agency programs include data collection, public education, training, and technology development.[69]

The federal government has one other program that supports federal and state wildfire protection efforts—the National Interagency Fire Center (NIFC). The center was established by the BLM and the FS in Boise, ID, in 1965 to coordinate fire protection efforts (especially aviation support) in the intermountain west. The early successes led to the inclusion of the National Weather Service (in the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce) and of the other DOI agencies with fire suppression responsibilities (the National Park Service, Fish and Wildlife Service, Bureau of Indian Affairs, and Office of Aircraft Services). (FEMA is not included in the NIFC.) NIFC also coordinates with the National Association of State Foresters to assist in the efficient use of federal, state, and local firefighting resources in areas where wildfires are burning.

Disaster Relief

The federal government also provides relief following many disasters, to assist recovery by state and local governments and especially the private sector (including the insurance industry). The federal land management agencies generally do not provide disaster relief, although there has been some economic assistance for communities affected by wildfires upon occasion, as described above. Wildfire operations funding includes money for emergency rehabilitation, to reduce the possibility of significant erosion, stream sedimentation, and mass soil movement (landslides) from burned areas of federal lands. While not direct relief for affected communities, such efforts may prevent flooding and debris flows that can exacerbate local economic and social problems caused by catastrophic fires. Two authorized programs, FS Emergency Reforestation Assistance and USDA Emergency Forest Restoration, can aid private landowners whose lands were damaged by wildfire, but the programs have not been funded in recent years.[70]

FEMA is the principal federal agency that provides relief following declared disasters, although local, state, and other federal agencies (e.g., the Farm Service Agency and the Small Business Administration) also have emergency assistance programs.[71] The Stafford Act established a process for Governors to request the President to declare a disaster, and public and individual assistance programs for disaster victims.

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[68] The annual funding for these programs is not distinguished in the agency's annual budget justification, and thus is not included in this report. See CRS Report RL34004, *Homeland Security Department: FY2008 Appropriations*, coordinated by Jennifer E. Lake.

[69] See CRS Report RS20071, *United States Fire Administration: An Overview*, by Lennard G. Kruger.

[70] See CRS Report RL31065, *Forestry Assistance Programs*, by Ross W. Gorte, p. 10.

[71] See CRS Report RL31734, *Federal Disaster Recovery Programs: Brief Summaries*, by Mary B. Jordan.

If the risk of catastrophic fires destroying homes and communities continues to escalate, as some have suggested, requests for wildfire disaster relief would also likely rise. This might lead some to argue that a federal insurance mechanism might be a more efficient and equitable system for sharing the risk. Federal crop insurance and national flood insurance have existed for many years, while federal insurance for other catastrophic risks (e.g., hurricanes, tornados, earthquakes, volcanoes) has also been debated.[72] An analysis of these alternative systems is beyond the scope of this report, but these might provide alternative approaches that could be adapted for federal wildfire insurance, if such insurance were seen as appropriate. Some observers, however, object to compensating landowners for building in what critics identify as unsafe areas.[73]

Current Issues

The severe fire seasons in recent years have raised many wildfire issues for Congress and the public. There have been spirited discussions about the effects of land management practices, especially timber sales, on fuel loads. A broad range of opinion exists on this issue, but most observers generally accept that current fuel loads reflect the aggressive fire suppression of the past century as well as historic logging and grazing practices. Some argue that catastrophic wildfires are nature's way of rejuvenating forests that have been mismanaged in extracting timber, and that the fires should be allowed to burn to restore the natural conditions.[74] Others argue that the catastrophic fires are due to increased fuel loads that have resulted from reduced logging in the national forests over the past decade, and that more logging could contribute significantly to reducing fuel loads and thus to protecting homes and communities.[75] However, the extent to which timber harvests affect the extent and severity of current and future wildfires cannot be determined from available data.[76] Some critics suggest that historic mismanagement—excessive fire suppression and past logging and grazing practices—by the FS warrants wholesale decentralization or revision of the management authority governing the National Forest System.[77]

Research information on causative factors and on the complex circumstances surrounding wildfire is limited. The value of wildfires as case studies for building predictive models is constrained, because the *a priori* situation (e.g., fuel loads and distribution) and burning conditions (e.g., wind and moisture levels, patterns, and variations) are often unknown. Experimental fires in the wild would be more useful, but are dangerous and generally unacceptable to the public. Prescribed fires could be used for research, but the burning conditions are necessarily restricted. Fires in the laboratory are feasible, but often cannot duplicate the complexity and variability of field conditions. Thus, research on fire protection and control is

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[72] See CRS Report RS21212, *Agricultural Disaster Assistance*, by Ralph M. Chite, and CRS Report RL34367, *Side-by-Side Comparison of Flood Insurance Reform Legislation in the 110th Congress*, by Rawle O. King

[73] Personal communication with Tim Hermach, Founder and President, Native Forest Council, Eugene, OR, on Oct. 18, 2000.

[74] Personal communication with Tim Hermach, Founder and President, Native Forest Council, Eugene, OR, on Sept. 26, 2000.

[75] William N. Dennison, Plumas County Supervisor, District 3, "Statement," *Hearing on the Use of Fire as a Management Tool and Its Risks and Benefits for Forest Health and Air Quality*, House Committee on Resources, Sept. 30, 1997, Serial No. 105-45, GPO, Washington, DC, 1997, pp. 107-116.

[76] See CRS Congressional Distribution Memorandum, *Forest Fires and Forest Management*, by Ross W. Gorte, Sept. 20, 2000.

[77] Nelson, *A Burning Issue*; O'Toole, *Reforming the Fire Service*.

challenging, and predictive tools for fire protection and control are often based substantially on expert opinion and anecdotes, rather than on documented research evidence.[78]

Concerns over forest and rangeland health, particularly related to fuel loads, have been discussed for nearly two decades; a major conference on forest ecosystem health was held in Idaho in 1993.[79] Significant funding to address these concerns, however, was not proposed until September 2000. While higher funding for wildfire protection, including fuel reduction, has persisted, some question whether this additional funding is sufficient to adequately reduce fuel loads. In 1999, GAO estimated that it would cost $725 million *annually*—nearly $12 billion through 2015—to reduce fuels using traditional treatment methods on the 39 million FS acres that were estimated to be at high risk of catastrophic wildfire.[80] This is nearly double the significantly increased appropriations for FS fuel reduction since FY2001.

The cost of a comprehensive fuel reduction program, as many advocate, would likely exceed the GAO estimate of $12 billion, because the scope of potential costs and proposed programs has increased. The FS estimate of FS acres at high risk of ecological loss due to catastrophic fire increased from 39 million acres in 1999 to 51 million acres in 2003. In addition, the GAO cost figure (received from the FS) of $300 per acre on average for fuel reduction might be low. One might anticipate more careful federal prescribed burning after the May 2000 escaped prescribed fire burned 239 homes in Los Alamos, NM; more cautious prescribed burning is likely to have higher unit costs than the GAO figure. Also, many advocate emphasizing fuel reduction in the wildland-urban interface, and treatment costs in the interface are higher, because of risks to homes and other structures from prescribed burning and because of possible damage to aesthetics from mechanical treatments.

GAO also addressed a subset of the widely-advocated comprehensive fuel reduction program, by estimating the cost for the initial treatment of FS high-risk acres. The FS has estimated that there are 23 million high-risk acres of DOI land and 107 million high-risk acres of other land. In addition, many advocate reducing fuels on lands at moderate risk—80 million FS acres, 76 million DOI acres, and 313 million other acres. Finally, in frequent-fire ecosystems, retreatment would be needed on the 5-35 year fire cycle (depending on the ecosystem), suggesting that fuel management costs would need to be continued beyond the 16-year program examined by GAO.

If a comprehensive program were undertaken to reduce fuels on all high-risk and moderate-risk federal lands, using GAO's treatment cost rate of $300 per acre, the total cost would come to $69 *billion*—$39 billion for FS lands and $30 billion for DOI lands—for initial treatment. This would come to $4.3 billion annually over 16 years, whereas the Administration's requested budget for fuel treatment in FY2008 was $499.8 million ($297.0 million for the FS and $202.8 million for the BLM), a little more than 10% of what some implicitly propose. This raises questions about whether a comprehensive fuel reduction program is feasible and how to prioritize treatment efforts.

There is a final significant question: would it work? The answer depends, in part, on how one defines successful fire protection. Fuel reduction might help restore "more natural" conditions to

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[78] Fire experts typically believe (and must believe, to do their jobs effectively) that catastrophic wildfires can and should be controlled; thus, their opinions may be biased, overstating the effectiveness and efficiency of control efforts.

[79] *Assessing Forest Ecosystem Health in the Inland West: November 14th-20th, 1993*. See footnote 8.

[80] GAO, *Cohesive Strategy Needed*.

forests and rangelands, as many advocate, and would likely yield some social benefits (e.g., improved water quality, more habitat for fire-dependent animal species). Others, however, advocate fuel reduction to allow greater use of forests and rangelands, for timber production, recreation, water yield, etc. Fuel reduction will certainly not reduce the conflict over the goals and purposes of having and managing federal lands. Reducing fuel loads might reduce acreage burned and the severity and damages of the wildfires that occur. Research is needed in various ecosystems to document and quantify the relationships among fuel loads and damages and the probability of catastrophic wildfires, to examine whether the cost of fuel reduction is justified by the lower fire risk and damage. However, it should also be recognized that, regardless of the extent of fuel reduction and other fire protection efforts, as long as there is biomass for burning, especially under severe weather conditions (drought and high wind), catastrophic wildfires will occasionally occur, with the attendant damages to resources, destruction of nearby homes, other economic and social impacts, and potential loss of life.

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