



Wildfire Fuels and Fuel Reduction

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Summary

Severe wildfires have been burning more acres and more structures in recent years. Some assert that climate change is at least partly to blame; others claim that the increasing number of homes in and near the forest (the *wildland-urban interface*) is a major cause. However, most observers agree that wildfire suppression and historic land management practices have led to unnaturally high accumulations of biomass in many forests, particularly in the intermountain West. While high-intensity conflagrations (wildfires that burn the forest canopy) occur naturally in some ecosystems (called crown-fire or stand-replacement fire ecosystems), abnormally high biomass levels can lead to conflagrations in ecosystems when such crown fires were rare (called frequent-surface-fire ecosystems). Thus, many propose activities to reduce forest biomass fuels.

The characteristics of forest biomass fuels affect the nature, spread, and intensity of the fire. Fuel moisture content is critical, but is generally a function of weather patterns over hours, days, and weeks. Fuel size is also important—fine and small fuels (e.g., needles, grasses, leaves, small twigs) are key to fire spread, while larger fuels (e.g., twigs larger than pencil-diameter, branches, and logs) contribute primarily to fire intensity; both are important to minimizing fire damages. Fuel distribution can also affect damages. Relatively continuous fuels improve burning, and vertically continuous fuels—fuel ladders—can lead a surface fire into the canopy, causing a conflagration. Total fuel accumulations (fuel loads) also contribute to fire intensity and damage. Thus, activities that alter biomass fuels—reducing total loads, reducing small fuels, reducing large fuels, and eliminating fuel ladders—can help reduce wildfire severity and damages.

Several tools can be used to reduce forest biomass fuels. Prescribed burning is the deliberate use of fire in specific areas under specified conditions. It is the only tool that can eliminate fine fuels, but is risky because it burns any fuel available. Wildland fire use is the term used for allowing a wildfire to be used like a prescribed burn (i.e., within specified areas and conditions). Thinning is a broader forestry tool useful for eliminating fuel ladders and total fuels in the crown, but it does not eliminate fine fuels, and it concentrates fuels in a more continuous array on the surface. The combination of thinning with prescribed burning is often proposed to combine the benefits, but it also combines the cost of both. Logging does little to reduce fuel loads.

The federal land management agencies undertake all of these activities under general authorities for wildfire protection and land and resource management. Fuel reduction, primarily via prescribed burning, is funded with direct annual appropriations for wildfire management. Other activities, particularly thinning, are funded through other annual appropriations accounts, such as vegetation management. Also, several mandatory spending accounts provide funds for related activities, such as treating logging and thinning debris. In addition, wildfire assistance funding allows the Forest Service to provide technical and financial aid for reducing forest biomass fuel loads on nonfederal lands, among other things.

The issues for Congress include the appropriate level of funding for prescribed burning and thinning for fuel reduction and the appropriate reporting of accomplishments. Current reporting does not identify ecosystems being treated and the effectiveness of the treatments. Similarly, current appropriations and reporting do not distinguish thinning for fuel reduction from thinning for other purposes, such as enhancing timber productivity. More complete reporting could allow Congress to better target its appropriations for fuel reduction to enhance wildfire protection.

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Recent fire seasons have been getting more severe, with more acres burned and more damage to property and resources. More acres burned in 2004, 2005, 2006, 2007, 2011, and 2012 than in any other years since record-keeping began in 1960.¹ Many assert that the threat of severe wildfires and the cost of suppressing fires have grown because many forests have unnaturally high amounts of biomass to fuel the fires, as well as because of climate change and the increasing numbers of homes in and near forests (the *wildland-urban interface*).² Further, many believe that federal efforts to reduce biomass accumulations to historically natural levels have been hindered by public concerns about the impacts; others contend that some proposed activities will lead to commercial timber harvests with little or no fire protection benefits. Congress is considering proposals to authorize and/or fund various activities to reduce biomass fuels and to alter the public review processes for some of those actions (e.g., H.R. 1345).

This report examines wildfire biomass fuels. It begins with a discussion of fuel characteristics and their relation to wildfire intensity and spread. This is followed with a description of actions proposed to reduce biomass fuel levels, their effectiveness for protecting property and resources from wildfires, and their impacts on other resource values. It concludes with an examination of the federal authorities for fuel reduction activities on federal and nonfederal lands, together with data on the funding provided under each of these authorities.

Issues for Congress

Severe wildfires have been burning more structures and more area. Many believe a significant cause is unnaturally high accumulations of biomass, and have proposed that Congress provide more funding and broader authority for activities that reduce biomass fuels, and thus reduce the extent and severity of wildfires. The principal tools to reduce biomass fuels are prescribed burning—deliberate use of fire primarily to eliminate fine fuels—and thinning—cutting some vegetation to reduce understory growth, the density of the forest canopy, and the fuel ladders that can allow fires to move from the surface into the canopy.

The existing authorities for federal agencies to reduce biomass fuel for wildfire protection are broad, though indirect. Congress enacts annual appropriations for hazardous fuels treatments and for other management activities that can encompass fuel reduction efforts. However, the reporting on hazardous fuel treatment funding for the various types of fuel reduction activities and on accomplishments are insufficient for Congress to assess progress in reducing biomass fuels. Also, information on funding (from annual appropriations and mandatory accounts) used for thinning and other activities that are substantially intended for wildfire protection, and reporting on results, are inadequate to compare the benefits and costs of these activities and funds. Distinguishing data on funding and accomplishments via prescribed burning, thinning, and other fuel reduction efforts by ecosystem or fire regime, and separating results from wildland fire use, would likely improve the understanding of the nature, extent, and results of appropriations. Improved reporting on funding and on results, with information disaggregated by ecosystem or fire regime, may help Congress in its deliberations over appropriate funding allocations among activities and agencies.

¹ National Interagency Fire Center, Total Wildland Fire and Acres.

² For a more detailed discussion, see CRS Report RS21880, *Wildfire Protection in the Wildland-Urban Interface*.

Biomass Fuels for Wildfires

All biomass is potentially fuel for wildfires. In temperate ecosystems, wildfires are inevitable, because dry conditions and ignitions (natural, such as lightning, and anthropogenic, such as matches and campfires) occur. Some wildfires are low-intensity, surface fires that burn the surface fuels (e.g., grasses, needles, leaves). Other fires, under certain conditions become high-intensity conflagrations (crown fires) that burn through the forest canopy, killing many of the standing trees.

Whether a wildfire is a surface fire (which can be controlled readily) or a crown fire (which cannot) depends on the fuel characteristics and the weather (wind, recent precipitation, and recent and current relative humidity). Since weather is uncontrollable, fire protection efforts focus on altering fuel characteristics to try to prevent or minimize the damages caused by crown fires.³

Fuel Characteristics

Four characteristics of biomass fuels significantly affect wildfire behavior and fire effects: the moisture content of the fuels; the size (diameter) of the fuels; the distribution of the fuels (both horizontally and vertically); and the total quantity of the fuels.

Moisture Content

“Moisture content may be the most important single property controlling flammability of a given fuel.”⁴ This is because moisture in biomass requires heat to evaporate the moisture so the biomass can burn. The moisture content of green foliage fluctuates widely, depending largely on weather in the preceding days and weeks. Dead biomass also contains water, but at much lower levels than green foliage. Fuel with a moisture content of up to 20%-30% can be ignited (e.g., from a match or a chainsaw, or more commonly from lightning).⁵ However, once a fire is started, biomass with a moisture content of 100% can burn, especially if the fire is driven by high winds.⁶

Fuel Size

Potential wildfire fuels are generally described by the time (in hours) that it takes for the moisture content of the fuels to decline by about two-thirds.⁷ The smallest diameter fuels, also called fine fuels or flash fuels, are the 1-hour time lag fuels—needles, leaves, grass, and so forth—both on the surface and in the tree crowns that dry out (lose two-thirds of their moisture content) in about

³ Different efforts are needed for protecting structures. See CRS Report RL34517, *Wildfire Damages to Homes and Resources: Understanding Causes and Reducing Losses*.

⁴ 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, p. G-4.

⁵ Martin and Brackebusch, p. G-4.

⁶ In addition, some fuels (e.g., Manzanita and other species in the chaparral ecosystems of southern California and Arizona) contain volatile waxes and resins that increase their ignitability and energy released when they burn. (Martin and Brackebusch, p. G-8.)

⁷ Arthur A. Brown and Kenneth P. Davis, “Chapter 4: Forest Fuels,” in *Forest Fire Control and Use* (New York: McGraw-Hill Book Co., 1973), pp. 79-110.

an hour. The next size class is 10-hour time lag fuels—woody twigs and branches, up to a quarter-inch in diameter (about the diameter of a pencil). The larger size classes are the 100-hour time lag fuels (up to 3 inches in diameter) and 1,000-hour time lag fuels (more than 3 inches in diameter).

The fine or flash fuels are the most important for spreading fires because they ignite and burn quickly. However, the 1-hour time lag fuels contribute little to fire intensity and damage, because they have little mass to burn and because they burn so quickly (being completely consumed in a matter of minutes). The 10-hour time lag fuels also contribute substantially to the rate of spread, because they also ignite and burn quickly, and because winds can carry the burning fuels (known as firebrands) aloft, to be dropped ahead of the fire (thus starting a new, or spot, fire ahead of the current fire) or on the roofs of surrounding structures. Some 100-hour time-lag fuels can also become firebrands. The larger fuels—particularly the 1,000-hour time lag fuels—burn intensely, and thus generate much of the damage fires cause, but contribute little to the rate of spread, because they are slow to ignite and are too heavy to be carried aloft as firebrands.

Distribution of Fuels

Fuel distribution refers to its arrangement horizontally and vertically. Two measures are particularly important. One is the compactness (or porosity) of the fuels—how closely packed together the fuels are. Highly compact fuel beds are more resistant to burning, because the compaction reduces ventilation, slowing moisture loss in dry conditions and restricting air flow to the fire (since fire requires oxygen, as well as fuel and a heat source). Less compaction allows more air flow, both drying out the fuels and feeding the fire, at least until the fuel becomes so distributed that it breaks the continuity of the fuels.

Continuity is the other key measure of fuel distribution. Fires need relatively continuous fuels to spread; indeed, the entire purpose behind firelines is to control wildfires by breaking the continuity of the fuels. How wide a break is needed depends on several factors, such as fuel size and moisture content (which affect the ease or difficulty for fuels across the break to ignite), but especially slope and wind speed. Steep slopes and high winds bring the fire’s convection column closer to the fuel ahead of the fire, reducing fuel moisture content and raising temperatures, and thus making the fuel more flammable. High winds can also carry firebrands, thus spreading the fire across very wide firebreaks.⁸

Vertical continuity is also important. “Fuel ladders” are continuous fuels, especially of fine and small fuels, between the surface and the tree crowns. Ladders help spread fires into the canopy, thus turning a surface fire into a crown fire, by providing continuous fuels between the ground and the canopy, and when burning, by pre-heating the green foliage of the canopy (reducing its fuel moisture content and raising temperatures). Wind is often necessary to initiate and sustain a crown fire, since the green foliage typically has a higher moisture content than dead biomass on the surface. However, once started, a crown fire with strong convection can increase the winds, and thus increase its own intensity and spread.⁹

⁸ Spot fires have occurred miles ahead of the flame front from firebrands carried by high winds. (Brown and Davis, “Chapter 7: Forest Fire Behavior,” p. 199.)

⁹ Brown and Davis, “Chapter 7: Forest Fire Behavior,” pp. 197-205.

Fuel Quantity

The quantity of biomass fuels—the fuel load—varies widely. As measured by foresters, fuel loads typically exclude biomass in the live, commercially valuable trees. Thus, fuel loads include dead biomass (needles or leaves, branches that have fallen, and older dead cellulose), undergrowth (grasses and forbs, shrubs, and small trees), and undesirable trees (including those in stands too dense to produce commercially usable logs). Fuel loads can range from less than 1 ton (oven-dry) of biomass per acre in annual grasslands (e.g., stands of cheatgrass) to more than 200 tons per acre on recently clearcut sites (e.g., old-growth Douglas-fir stands).¹⁰ Despite the general exclusion of live crown biomass in the commercially valuable trees, the total mass, the density, and the continuity of the live crown biomass is a significant factor in sustaining crown fires.

Not all fuel is consumed (converted into its mineral components [ash] and smoke [water vapor, carbon dioxide, carbon monoxide, particulates, and more]) in a wildfire. Typically, the fine and small fuels are largely consumed, and the proportion consumed decreases as the size of the fuel increases. One researcher found that high intensity fires consumed 100% of the foliage and 75% of the understory vegetation, but only 10% of tree branches and 5% of large tree stems.¹¹ Thus, many large-diameter fuels remain on the site in the aftermath of a fire.

Fuels and Ecosystems

The nature of these fuel characteristics, and the resulting fire, is substantially affected by the nature of the various ecosystems. Some ecosystems are adapted to relatively frequent low-intensity surface fires. Others are adapted to periodic, high-intensity crown fires that kill much of the vegetation. Still others are adapted to a mixed regime, with some crown fire intermingled with surface fires. And still other ecosystems have evolved with little or no natural wildfire.¹²

Frequent Low-Intensity Surface-Fire Ecosystems

Many ecosystems in the United States are adapted to relatively frequent wildfires—at least every 30 years or so. These ecosystems are characterized by large amounts of fine fuels (typically grasses and needles), and include grasslands and meadows. Natural forested frequent-fire ecosystems are dominated by relatively large, fire-resistant trees, with open, park-like spaces because the frequent fires kill most of the seedlings and shrubs. The classic examples are ponderosa pine and the southern yellow pine ecosystems. These ecosystems have relatively few small to mid-sized trees to provide fuel ladders (though a few occasionally survive to replace the existing large trees), and thus crown fires are very infrequent. Surface-fire ecosystems account for about 34% of all U.S. wildlands.¹³

¹⁰ Martin and Brackebusch, p. G-5.

¹¹ James K. Agee, *Fire Ecology of Pacific Northwest Forests* (Washington, DC: Island Press, 1993), p. 42.

¹² Stephen F. Arno and Steven Allison-Bunnell, *Flames in Our Forest: Disaster or Renewal* (Washington, DC: Island Press, 2002), pp. 45-46.

¹³ Kirsten M. Schmidt, James P. Menakis, and Colin C. Hardy 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, p. 13.

Historically, the fuels in these ecosystems were composed primarily of grasses, needles, and small, low-growing shrubs. Heavy grazing in the West, beginning in the late 1800s, reduced grass cover, thus removing some of the fine fuels that carried the frequent surface fires and allowing fuel loads of branches and small to mid-size trees to expand. At the same time, logging often emphasized the large pines, leaving the smaller and less fire-resistant trees of the understory (the firs and spruces) to become more dominant. Effective fire suppression further contributed to the fuel loads by eliminating many of the frequent, low-intensity surface fires. Thus, in many places in the West, these ecosystems currently have fuel loads much higher than was historically natural, with fuel ladders where there were traditionally none.¹⁴ Hence, many frequent surface fire ecosystems are at risk of catastrophic crown fires, possibly altering these ecosystems substantially. Activities that reduce fuel loads and remove fuel ladders have been documented to reduce wildfire severity (intensity and damage) in surface-fire ecosystems.¹⁵

Periodic High-Intensity Crown-Fire Ecosystems

At the other end of the spectrum are ecosystems adapted to periodic, high-intensity crown fires. These ecosystems are characterized by large amounts of dense, relatively uniform fuels—plants of the same size and age that regenerated following the previous crown fire. Occasionally, the fires are relatively frequent—less than 50 years between fires—and many plants resprout from rootstocks that were not killed by the fire; the classic example is chaparral: a dense, xeric (arid) ecosystem dominated by large shrubs and small trees (e.g., oaks, Manzanitas, and many other species) common in southern California and parts of the Southwest. More typically, crown fires are infrequent—200 years or more between fires. Most trees are killed, but establish new stands in the burned areas. The classic example is lodgepole pine, a species that grows in dense, even-aged stands and produces *serotinous* cones that only open and release the seeds after they have been heated sufficiently by a fire. Crown-fire ecosystems account for about 42% of wildlands in the United States.¹⁶

These ecosystems contain relatively large volumes of biomass fuels of relatively uniform size. There is no evidence that human activities of the past century—grazing, logging, fire suppression, and more—have had much impact on fuel loads or on the nature of fires in these ecosystems. Similarly, there is no evidence that activities to reduce fuel loads and remove fuel ladders would affect the likelihood of catastrophic crown fires in these ecosystems. The ineffectiveness of fuel treatment was particularly noted for southern California chaparral: “large fires were not dependent on old age classes of fuels, and it is thus unlikely that age class manipulation of fuels can prevent large fires.”¹⁷

It should also be recognized that catastrophic crown fires do not completely destroy all vegetation in their paths. Wildfires respond to minor localized variations in moisture and in fuel size, load, and distribution, and thus typically are patchy. Even catastrophic fires in crown-fire ecosystems

¹⁴ *Assessing Forest Ecosystem Health in the Inland West: Papers from the American Forests Workshop, November 14th-20th, 1993, Sun Valley, Idaho*, ed. R. Neil Sampson and David L. Adams (New York: Food Products Press, 1994).

¹⁵ Philip N. Omi and Erik J. Martinson, *Final Report: Effect of Fuels Treatment on Wildfire Severity*, report submitted to the Joint Fire Science Program Governing Board, Colorado State Univ., Western Forest Fire Research Center, Ft. Collins, CO, March 25, 2002.

¹⁶ *Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management*, p. 13.

¹⁷ Jon E. Keeley, C.J. Fotheringham, and Marco Marais, “Reexamining Fire Suppression Impacts on Brushland Fire Regimes,” *Science*, vol. 284 (June 11, 1999), p. 1829.

leave some areas lightly burned or unburned. The Yellowstone fires (largely in lodgepole pine) that were reported on the nightly news for weeks in the summer of 1988 provide an excellent example: 30% of the reported burned area was actually unburned, and another 15-20% had only low-intensity surface fires.¹⁸ Thus, only about half the reported acres burned were actually burned severely.

Mixed Fire Regime Ecosystems

In addition to the patchy fires of crown fire ecosystems, some ecosystems consistently burn with crown fires of relatively limited scale, substantially mixed with low-intensity surface fires. These mixed-fire-regime ecosystems typically have an array of fuel sizes, including ladders to allow some crown fires, and often discontinuous crown canopies to halt the spread of crown fires. A classic example is whitebark pine, a slow-growing species commonly limited to high elevation sites. Whitebark pines grow slowly on harsh, windy sites, moderating the micro-climatic to allow true firs and spruces to germinate and grow. The sporadic mixed-intensity fires kill most of the competing firs and spruces and some of the pines, but some pines also survive to produce seed. Clark's nutcrackers are the primary means for spreading the seeds, and these birds prefer to "cache" seeds in burned areas, assuring regeneration of whitebark pines in the severely burned patches.¹⁹ Other species that are commonly surface-fire or crown-fire ecosystems can be mixed-fire-regime types under certain circumstances, typically near the transition to another area dominated by a different species. Ponderosa pine, for example, may be a mixed-fire type on relatively moist sites, where it mixes naturally with Douglas-fir, such as on north-facing slopes in the northern Rockies. Lodgepole pine can be a mixed fire type on relatively dry sites, where the trees naturally grow farther apart, such as on the eastern slopes of the Sierras.

Although they account for about 24% of U.S. wildlands,²⁰ less is known about the possible consequences of fuel reduction activities in mixed-fire-regime ecosystems. It is unclear whether fuels are at unnatural levels, sizes, and distributions, and thus it is unclear whether these ecosystems might experience abnormal levels and intensities of crown fires. It is also unclear whether fuel reduction activities would significantly alter wildfire extent or severity in these ecosystems.

Options for Fuel Reduction for Fire Protection

Many have proposed reducing fuel loads to increase the ability to suppress wildfires and to reduce the likelihood of crown fires, and thus reducing the extent and damage of wildfires. As noted above, this has been documented as a valid presumption in some ecosystems, and possibly valid in others. It is, however, not appropriate for all ecosystems. Furthermore, reducing fuel loads has little, if any, benefit for protecting structures and communities from wildfires.²¹

¹⁸ L. Jack Lyon, Mark H. Ruff, and Robert G. Hooper 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, January 2000, p. 44.

¹⁹ Diana F. Tomback, "Clark's Nutcracker: Agent of Regeneration," in *Whitebark Pine Ecology and Restoration*, ed. Diana F. Tomback, Stephen F. Arno, and Robert E. Keane (Washington, DC: Island Press, 2001), pp. 90-100.

²⁰ *Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management*, p. 13.

²¹ See CRS Report RL34517, *Wildfire Damages to Homes and Resources: Understanding Causes and Reducing Losses*.

Reducing the risk of crown fires might seem to provide protection for infrastructure in the wildland-urban interface, but evidence from the Hayman Fire in 2002 (the largest wildfire in Colorado history) shows the potential futility of such efforts. Of the 132 homes burned in the Hayman Fire, 70 (53%) “were destroyed in association with the occurrence of torching or crown fire in the home ignition zone. Sixty-two [47%] were destroyed by surface fire or firebrands.”²² A total of 662 homes (83% of the homes within the Hayman Fire perimeter) survived relatively unscathed, despite more than half the area being in high-severity (35%) and moderate-severity (16%) burns; some of these homes (the number and portion were not documented) likely survived despite crown fire around them. Reducing fuel loads might reduce the extent of wildfires in surface-fire ecosystems, but many observers have suggested the need to *expand* the area burned in low-intensity surface fires to maintain lower fuel loads and other more historically natural conditions and values.²³ Nonetheless, reducing fuel loads and eliminating fuel ladders may be necessary to the relatively safe existence and use of low-intensity wildfire and prescribed fire in surface-fire ecosystems.

A variety of activities have been proposed for reducing fuel loads and otherwise modifying fuel characteristics. The most common proposals are prescribed burning and thinning—alone or in combination—while other activities (e.g., release, pruning, salvage logging) are occasionally suggested. Some observers have cautioned, however, that such activities do not always reduce the risk of crown fires:

Thinning and prescribed fires can modify understory microclimate that was previously buffered by overstory vegetation ... Thinned stands (open tree canopies) allow solar radiation to penetrate to the forest floor, which then increases surface temperatures, decreases fire fuel moisture, and decreases relative humidity compared to unthinned stands—conditions that can increase surface fire intensity ... [and] may increase the likelihood that overstory crowns ignite....²⁴

Prescribed Burning

Prescribed burning is the deliberate use of fire in specific areas within prescribed fuel and weather conditions (e.g., fuel moisture content, relative humidity, wind speed). Some call the activity “controlled” burning, but this overstates reality: fire is a self-sustaining chemical reaction, and if conditions change (e.g., wind speed increases), prescribed fires can escape control and cause extensive damage (e.g., the Cerro Grande Fire was a prescribed fire that escaped control and burned 237 homes in Los Alamos, NM, in May 2000). Some observers include as prescribed burning naturally occurring fires that are allowed to burn because they are within acceptable areas and conditions, as prescribed in fire management plans. The agencies use the term *wildland fire use* for such fires; although they do not include them as prescribed fires, they do include the acres burned in wildland-fire-use fires as acres treated for fuel reduction.

²² Jack Cohen and Rick Stratton, “Home Destruction Within the Hayman Fire Perimeter,” *Hayman Fire Case Study*, USDA Forest Service, Rocky Mountain Research Station, Gen. Tech. Rept. RMRS-GTR-114, Ft. Collins, CO, September 2003, p. 294.

²³ See, for example, Stephen J. Pyne, “The Perils of Prescribed Fire: A Reconsideration,” *Natural Resources Journal*, vol. 41, no. 1 (Winter 2001), pp. 1-8; and USDA Forest Service, Pacific Northwest Research Station, “Benefits of Hindsight: Reestablishing Fire on the Landscape,” *Science Findings*, no. 36 (August 2001).

²⁴ Russell T. Graham, Sarah McCaffery, and Theresa N. Jain, *Science Basis for Changing Forest Structure to Modify Wildfire Behavior and Severity*, USDA Forest Service, Rocky Mountain Research Station, Gen. Tech. Rept. RMRS-GTR-120, Ft. Collins, CO, April 2004, p. 27.

Because of the relatively high moisture levels and low wind speeds, prescribed burning primarily eliminates the fine and small fuels. Burning and decomposition are the only means for reducing fine and small fuels. Burning converts the biomass to smoke (carbon dioxide, water vapor, fine particulates, and other pollutants) and ashes (minerals from the organic matter, readily available to feed new plant growth).

However, prescribed burning has its limitations. It has little effect on the large diameter fuels. Also, prescribed fire is not a discriminating tool for reducing tree density, crown density, and fuel ladders, since the fire burns whatever biomass is available, depending on a host of site-specific and micro-climatic conditions. Prescribed burning is also risky; several escaped prescribed fires have become notable wildfires, with houses and even lives lost. As a result, fire managers tend to err on the side of caution, with substantial (possibly excessive) personnel and equipment, and thus high implementation costs. Finally, the smoke can be a significant health hazard, especially since fire prescriptions tend toward high relative humidity and low wind speeds, which are often associated with inversions and stagnant air masses.

Wildland Fire Use

The federal land management agencies—the Forest Service in the Department of Agriculture, and the Bureau of Land Management (BLM), National Park Service, Fish and Wildlife Service, and Bureau of Indian Affairs in the Department of the Interior—have policies in place to allow fire managers to use a naturally-occurring fire to achieve fire management objectives. This practice is, in effect, allowing a wildfire to burn with monitoring, but not aggressive suppression efforts, when the location and conditions are appropriate. Wildland fire use has been called by various terms over the years—“let-burn,” prescribed natural fire, wildlife fire use, and appropriate management response. The effects and risks are similar to prescribed burning, and the acres “treated” in this way are now counted as fuel reduction treatments. The principal difference is simply the source of ignition (nature for wildland fire use and humans for prescribed burning).

Thinning

Thinning is the mechanical cutting and removing of some of the trees in a stand.²⁵ It can be commercial thinning, if the trees are large enough to be used for products (typically 4½ inches in diameter), or precommercial, if the trees are too small to be of commercial use. Exactly how thinning alters biomass fuels depends on the approach used and on what is done with the biomass left on the site. The three basic approaches to thinning are:

- Low thinning, or thinning from below, which removes the smallest trees and those with the poorest form;
- Crown thinning, or thinning from above, which removes the larger trees to open the canopy and stimulate growth on the remaining trees; and
- Selection thinning, which removes the least desirable trees for the future stand, commonly the less desirable species and trees with poorer form.

²⁵ For more information, see David M. Smith, Bruce C. Larson, and Matthew J. Kelty et al., *The Practice of Silviculture: Applied Forest Ecology*, 9th ed. (New York: John Wiley & Sons, 1997).

Thinning has several advantages over prescribed burning for reducing fuels. First, it is controlled; which trees are cut and which are left can be selected, and the operation can be halted at any time. Another advantage is that at least low thinning can emphasize eliminating ladder fuels. A third advantage of thinning is that it reduces crown density—most in a crown thinning, least in a low thinning. One report stated:

[T]hinning has the ability to more precisely create targeted stand structure than does prescribed fire.... Used alone, ... thinning, especially emphasizing the smaller trees and shrubs, can be effective in reducing the vertical fuel continuity that fosters initiation of crown fires. In addition, thinning of small material and pruning of branches are more precise methods than prescribed fire for targeting ladder fuels and specific fuel components....²⁶

Thinning also has several disadvantages compared with prescribed burning. It leaves “slash”—tree tops and limbs in a commercial thinning, whole trees in a precommercial thinning—on the ground at the site; this actually increases the fuel load in the short run. The slash must be treated to contribute to fuel reduction.²⁷ Mechanical treatments (e.g., crushing or chopping) are feasible in some forests, but most common slash treatments—lop-and-scatter (to accelerate decomposition); pile-and-burn, and chipping—are labor-intensive, and thus are costly operations.

It should be recognized that not all thinning is intended to reduce biomass fuels. Thinning is also used to increase biomass growth of the desired commercial trees—essentially concentrating the biomass growth on fewer stems to produce larger, more valuable trees. As noted, this can leave slash on the ground, increasing fire hazards at least in the short run. Also, in crown-fire ecosystems, thinning provides little, if any, effective wildfire protection. Nonetheless, in surface-fire and mixed-fire regime ecosystems, and with slash treatment to reduce the fire hazard, thinning can be a tool to reduce the likelihood of catastrophic crown fires.

Thinning With Prescribed Burning

A common proposal is to combine thinning with prescribed burning—thinning first to eliminate ladder fuels and reduce crown density, followed by prescribed burning to eliminate the fine and small fuels in thinning slash. This seems a logical combination, with the benefits of each offsetting the liabilities of the other. However, the empirical evidence of the effectiveness of such combined operations is limited, and has shown variable results.²⁸ Furthermore, since each operation is costly, the combined treatment is much more expensive than any alternative.

²⁶ Graham, McCaffery, and Jain, *Scientific Basis for Changing Forest Structure*, p. 25.

²⁷ Programs to remove such biomass and produce energy exist, and more are being discussed, but biomass energy programs to use biomass wastes from the forest are beyond the scope of this report. For more information, see CRS Report R40529, *Biomass: Comparison of Definitions in Legislation Through the 112th Congress*, CRS Report R40565, *Biomass Resources: The Southeastern United States and the Renewable Electricity Standard Debate*; and CRS Report RL34130, *Renewable Energy Programs in the 2008 Farm Bill*.

²⁸ Henry Carey and Martha Schumann, *Modifying Wildfire Behavior—The Effectiveness of Fuel Treatments: The Status of Our Knowledge*, National Community Forestry Center, Southwest Region Working Paper 2, Santa Fe, NM, April 2003, pp. i-ii.

Other Activities

Various other activities are sometimes proposed to reduce fuel loads. Logging is sometimes suggested, especially salvage logging of stands with a high proportion of dead trees. Commercial logging emphasizes removal of large standing trees. (Dead trees that have fallen usually have deteriorated too much for wood products.) Logging does reduce crown density (completely in clearcutting), but does little for fuel ladders and leaves substantial volumes of slash. As researchers have noted:

The proposal that **commercial logging** can reduce the incidence of canopy fires was untested in the scientific literature. Commercial logging focuses on large diameter trees and does not address crown base height—the branches, seedlings and saplings which contribute so significantly to the “ladder effect” in wildfire behavior.²⁹ (emphasis in original)

Salvage of standing dead trees might reduce fuels, but some observers have noted that standing dead trees that have shed their needles may contribute less to the intensity and spread of crown fires than live trees, because of their lack of fine fuels.³⁰

Pruning trees is another activity that can be used to alter fuels for wildfire protection. Pruning focuses on removing lower tree branches, which eliminates many fuel ladders and can reduce crown density. However, as with thinning and logging, pruning leaves slash on the ground, which can contribute to fire intensity and spread unless and until treated.

Fuel Reduction Authorities and Programs

Five federal agencies are responsible for wildfire protection of the federal lands they administer: the Forest Service (FS) in the Department of Agriculture, and the Bureau of Land Management (BLM), National Park Service (NPS), Fish and Wildlife Service (FWS), and Bureau of Indian Affairs (BIA) in the Department of the Interior (DOI).

None of the agencies are explicitly authorized or directed to reduce biomass fuels on its lands. Rather, each is implicitly authorized to reduce fuels for wildfire protection within its mandate to preserve and protect the lands and resources under its jurisdiction. Since 1897, for example, the FS (and its predecessor agencies) has been directed to “make provisions for the protection against destruction by fire and depredations upon the public forests and forest reservations” (renamed national forests in 1907).³¹ In 1916, when the NPS was created, Congress directed management “to conserve the scenery and the natural and historic objects, and the wild life” of its lands.³²

²⁹ Carey and Schumann, *Modifying Wildfire Behavior*, p. i-ii.

³⁰ See Merrill R. Kaufmann, Gregory H. Aplet, and Mike Babler et al., *The Status of Our Scientific Understanding of Lodgepole Pine and Mountain Pine Beetles—A Focus on Forest Ecology and Fire Behavior*, The Nature Conservancy, GFI Tech. Rept. 2008-2, Arlington, VA, 2008, pp. 11-14.; and W.H. Romme, J. Clement, and J. Hicke et al., *Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests: A Brief Synthesis of Relevant Research*, Colorado State Univ., Colorado Forest Restoration Institute; Colorado State Forest Service; and Univ. of Idaho, pp. 8-10.

³¹ Act of June 4, 1897, Sundry Civil Expenses Appropriations for FY1898, §1, 8th unnumbered paragraph under “Surveying the Public Lands;” 16 U.S.C. §551.

³² Act of August 25, 1916, §1; 16 U.S.C. §1.

Implicit BLM authority was provided in the Federal Land Policy and Management Act of 1976 (FLPMA):³³

the public lands shall be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use....

FWS management direction is similarly broad: “for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats ... for the benefit of present and future generations of Americans.”³⁴

The BIA has the most explicit direction; Indian forest land management activities are defined to include³⁵

(C) forest land development, including forestation, thinning, tree improvement activities and the use of silvicultural treatments to restore or increase growth and yield to the full productive capacity of the forest environment; [and]

(D) protection against losses from wildfire, *including* ... construction of firebreaks, hazard reduction, prescribed burning ... [emphasis added]

Despite the general, broad, generic authority for biomass fuel reduction activities (prescribed burning, thinning, and more), the agencies have both specific funding programs and the authority to use general management funds for these types of activities. Below is a description of each agency’s relevant programs.

Forest Service

The Forest Service has several accounts which fund activities that can reduce biomass fuels. The primary funding for prescribed burning is the Hazardous Fuels sub-account, within the Other Operations account of the Wildland Fire Management line item. Although this sub-account is the primary source of funds for prescribed burning, it can be used for other fuel reduction activities, such as thinning, as well. How much Hazardous Fuels funding is used for prescribed burning or for other activities, and which ecosystems (specifically or by fire regime) the activities occur in, are not reported.³⁶ As shown in **Table 1**, Hazardous Fuels funding rose substantially in FY2001, then continued to rise steadily through FY2008, before jumping again in FY2009 due to the substantial funding in the economic stimulus legislation (P.L. 111-5), and then declining over the last few years to more than half of the FY2009 funding total.

³³ P.L. 94-579, §102; 43 U.S.C. §1701(a)(8).

³⁴ National Wildlife Refuge System Administration Act of 1966, P.L. 91-135, as amended by the National Wildlife Refuge Improvement Act of 1997, P.L. 105-57; 16 U.S.C. §668dd(a)(2).

³⁵ National Indian Forest Resources Management Act, Title III of P.L. 101-630; 25 U.S.C. §3103(4).

³⁶ The FS budget justification provides some hazardous fuel reduction performance measures (e.g., acres of wildland-urban interface high-priority hazardous fuels treated), but does not give details about the hazardous fuel removal treatment type (e.g., prescribed burning, thinning).

Thinning—for fuel reduction as well as for other purposes (e.g., enhancing timber production)—is funded within the Vegetation and Watershed Management account of the National Forest System line item. This account also includes reforestation, rangeland improvements (e.g., grass seeding), watershed protection (e.g., slope stabilization), noxious weed control and eradication, and air quality (e.g., smoke) management efforts. In FY2008, about 20% of appropriations to this account funded thinning and related activities (e.g., pruning); however, the portion used for thinning varies from year to year. In addition, the portion of thinning funded through Vegetation Management that is primarily intended to improve wildfire protection is unknown.

Table I. Federal Lands Fuel Reduction Funding, FY1999-FY2013

(in millions of dollars)

	FS	DOI	Total
FY1999	65.0	33.8 ^a	98.8
FY2000	70.0	47.0	117.0
FY2001	205.2	195.0	400.2
FY2002	209.0	186.2	395.2
FY2003	236.6	185.6	422.2
FY2004	258.3	183.6	441.9
FY2005	292.5	201.4	493.9
FY2006	280.1	208.1	488.2
FY2007	301.3	199.8	501.1
FY2008	410.1	209.6	619.7
FY2009	584.6 ^b	218.1 ^c	907.7
FY2010	345.3	206.2	556.5
FY2011	344.6	183.3	527.9
FY2012	312.1	183.0	495.1
FY2013 ^d	317.1	145.3	462.4

Source: Data compiled by CRS. For more information, see CRS Report RL33990, *Federal Funding for Wildfire Control and Management*.

- a. Calculated at 26% of wildfire operations (see page IV-36 of the FY2001 BLM budget justification).
- b. Includes \$339.6 million in the Omnibus Appropriations Act (P.L. 111-8) and \$250.0 million in the economic stimulus legislation (P.L. 111-5).
- c. Includes \$203.1 million in the Omnibus Appropriations Act (P.L. 111-8) and \$15.0 million in the economic stimulus legislation (P.L. 111-5).
- d. Data provided do not take into account the Joint Committee sequester for FY2013. Data obtained from FS and DOI budget justifications.

The FS has three mandatory spending accounts that also provide funds for activities that can reduce biomass fuels. One is Brush Disposal (BD); this account collects deposits from timber purchasers to be used by the FS to treat the slash from logging operations in the national forests.³⁷

³⁷ 16 U.S.C. §490.

Slash treatments include mechanical efforts (crushing, bulldozer-piling), manual efforts (e.g., lopping-and-scattering, hand-piling), and prescribed burning (broadcast burning, burning slash piles). Although the funds are to be used on timber sale areas, slash treatment following thinning operations is also sometimes funded through the BD account. These activities are typically not counted as fuel reduction efforts, but the primary purpose of slash treatment is to reduce fire hazards.³⁸

Another mandatory spending account is the Knutson-Vandenberg (K-V) Fund.³⁹ This account also collects deposits from timber purchasers, to be used by the FS to reforest and otherwise improve the forest following logging operations (such as through thinning, watershed protection, etc.). Thus, K-V funds can be used in a manner similar to Vegetation and Watershed Management Appropriations. Again, how much funding is used for thinning and the portion of thinning that improves wildfire protection are unknown.⁴⁰

The third relevant FS mandatory spending account is stewardship contracting.⁴¹ The FS is authorized to include forest stewardship activities, such as thinning for fuel reduction, as requirements in these timber sale contracts.⁴² Deposits to this account occur when the contracts generate net receipts (i.e., the value of the timber harvested exceeds the cost of the stewardship activities). The funds can then be used on a variety of activities, including thinning. The agency does not report how much thinning is funded and the portion that improves wildfire protection.⁴³

Department of the Interior

The four agencies within DOI receive appropriations in accounts similar to the FS accounts. The Hazardous Fuels sub-account, within the Other Operations account of the Wildland Fire Management line item, provides the majority of funding for prescribed burning, although the funds can be used for other fuel reduction activities. The portion used for prescribed burning, and the ecosystems treated by each method, are not reported. Wildland Fire Management is now funded as a Department-wide program; prior to FY2008, Wildland Fire Management was funded through the BLM, with the BLM allocating funds to each of the other agencies. As shown in **Table 1**, DOI fuel reduction funding in the Hazardous Fuels sub-account jumped in FY2001, and has been relatively stable since.

Other fuel reduction activities, such as thinning, are funded through general land and resource management accounts for each of the DOI agencies. These funds can be used for various activities that might improve wildfire protection by reducing fuel loads. For the BLM, the principal account is Land Resources, within the Management of Lands and Resources line item;

³⁸ Smith, Larson, Kelty et al., *The Practice of Silviculture*.

³⁹ 16 U.S.C. §576.

⁴⁰ The FS budget justification provides performance measures for the K-V fund (e.g., acres of hazardous fuels treated to reduce risk of catastrophic fire), but does not give details about the hazardous fuel treatment type (e.g., prescribed burning, thinning).

⁴¹ This authority is also available for the Bureau of Land Management.

⁴² See CRS Report RS20985, *Stewardship Contracting for Federal Forests*, by Ross W. Gorte.

⁴³ The FS budget justification provides key accomplishments for stewardship contracting (e.g., acres of wildland-urban interface hazardous fuels treated), but does not give details about the hazardous fuel treatment type (e.g., prescribed burning, thinning).

the BLM also receives funds for the Western Oregon Resources Management account within the Oregon and California (O&C) Grant Lands line item. Funds from both accounts could be used for activities that reduce biomass fuels. The NPS has two accounts, Park Protection and Resource Stewardship, both within the Operation of the National Park System line item; both fund activities to protect and restore natural and cultural resources, and thus could fund fuel reduction activities that reduce wildfire threats. For the FWS, several accounts within the Resource Management line item could fund activities that reduce wildfire threats to migratory birds, wildlife habitats, and the National Wildlife Refuge System. The BIA has several sub-accounts within the Trust—Natural Resources Management account of the Operation of Indian Programs line item that could fund activities that reduce wildfire threats on Indian lands. However, the portion of the funds from each of these accounts used for fuel reduction activities is unknown.

The BLM has one mandatory spending account that can be used for activities that reduce biomass fuels to improve wildfire protection: the Forest Ecosystem Health and Recovery Fund.⁴⁴ These funds can be used for a variety of activities, including reducing wildfire risk for damaged forests (e.g., having high tree mortality due to an insect infestation or disease epidemic). The portion that might be used to improve wildfire protection is unknown.

Authorities to Assist Fuel Reduction on Nonfederal Lands

As with fuel reduction authorities for federal lands, federal authorities for assisting fuel reduction on nonfederal lands are indirect, at best. The FS has two wildfire protection assistance programs that can include fuel reduction.⁴⁵ None of the other agencies have financial and technical assistance programs for state or local governments or private landowners that can be used for biomass fuel reduction activities.

One FS wildfire protection assistance program is State Fire Assistance (also called Rural Fire Protection). Funding is authorized for technical and financial assistance to states for fire prevention, fire control, and prescribed burning for fire protection. Allocation to the states is based on a non-statutory formula (at the agency's discretion), and the portion used for fuel reduction via prescribed burning is at each state's discretion.

The other FS wildfire protection assistance program is Volunteer Fire Assistance. The FS is authorized to provide technical and financial assistance for fire prevention, fire control, and prescribed burning for fire protection. Eligibility is limited to rural volunteer fire departments, defined as "any organized, not for profit, fire protection organization that provides service primarily to a community or city" of up to 10,000 people "whose firefighting personnel is 80 percent or more volunteer, and that is recognized as a fire department by the laws of the State ...". Allocation is at the agency's discretion, and any funding used for fuel reduction is at the local fire department's discretion.

⁴⁴ This account was created in an unnumbered paragraph of the FY1993 Interior appropriations act (P.L. 102-381) and amended in an unnumbered paragraph of the FY1998 Interior appropriations act (P.L. 105-83). It is not codified. BLM reports in its FY2014 budget justification that "funds in this account are derived from the federal share of receipts from all BLM timber salvage sales, and from BLM forest health restoration treatments funded by this account" and that "the initial purpose of this fund was to allow quick response to fire and for reforestation of forests damaged by insects, disease, and fire."

⁴⁵ For more information, see CRS Report RL31065, *Forestry Assistance Programs*.

The FS is also authorized to support Community Wildfire Protection. The program was created in the 2002 farm bill (P.L. 107-171) in part to expand homeowner and community outreach and education (including community wildfire protection planning) and to establish defensible space around private homes and property. The FS is authorized to reduce biomass fuels on private lands (among other things) with the landowner's consent. To date, no funds have been appropriated for this program, although State Fire Assistance funding could be used to implement the program.

The FS also has other technical and financial assistance programs that might be used to assist in reducing fuels on nonfederal lands.⁴⁶ Various programs provide financial and technical assistance for forest stewardship (including thinning), forest health protection (including insect and disease control), and emergency restoration for forests damaged by natural disasters (including clearing downed trees). The portion of funds appropriated to these several programs that might contribute to wildfire protection through biomass fuel reduction is unknown.

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⁴⁶ See CRS Report RL31065, *Forestry Assistance Programs*, by Megan Stubbs.