Forest Health in the Rockies:

Human Needs and Ecological Reality

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Healthy forests embody the scenic beauty and environmental quality of the Rockies. From desert shrublands to lodgepole pine stands, forests cover much of the eight-state Rockies Region—68 percent by one estimate.[1] These forests provide critical wildlife habitat, protect watersheds, and sequester carbon dioxide. Forests also supply the region with economic resources, including recreational amenities and timber resources. Protecting these forests for future generations requires an integrated assessment of their health, ecosystem cycles, future climate change, urban growth patterns, and public policies. However, managing vast forested areas is costly, existing environmental regulations restrict development within forests, more people now live near our national forests, and public opposition has challenged some forest management techniques such as prescribed burns and salvage logging. This report examines how fire, insects and disease, and development have affected regional forest health and briefly discusses the history of land management in the Rockies.

Forest Health Defined

The text *Forest Health and Protection* defines healthy forests as those "that sustain their complexity while providing for human needs."[2] Ecosystem complexity can be described by basic qualities of the natural forest ecosystem (stand densities,[3] species composition, resource competition, and nutrient cycles) and disturbance factors such as the amount of disease or insect infestation in the forest and the current fire regime compared to its historical variability. Human needs include recreation, timber production, watershed protection, carbon sequestration, and minimal fire risk to life and property. Successful land management and development in the Rockies must balance both ecosystem and human needs to maintain healthy forests.

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Public Forest Managers in the Rockies

Future forest health in the Rockies Region is highly dependent on public land managers and their available resources. In the Rockies, approximately two-thirds of forests are publicly owned by the U.S. Forest Service, Bureau of Land Management, and Bureau of Indian Affairs.[4] As shown in Figure 1 and Table 1, total federal land ownership in the Rockies equals 58 percent and is dominated by the Bureau of Land Management (26 percent), U.S. Forest Service (19 percent), and Bureau of Indian Affairs (8 percent). Other federal agencies account for the remaining five percent, such as the U.S. Fish and Wildlife Service, the National Park Service, and the Department of Defense. Figure 2 presents the federal land ownership in each Rockies state, with Nevada reaching 88 percent public ownership. For comparison, public land ownership by census division is shown in Figure 3 and Table 2. Of all the U.S. census divisions, the Mountain Division is second only to the Pacific Division in federal land holdings (58 versus 74 percent, respectively), the latter dominated by BLM and U.S. Fish and Wildlife Service lands in Alaska. The average proportion of federal land ownership in the remaining seven census divisions equals 8 percent, suggesting that federal land management practices will have a stronger influence in the Western United States relative to the populous Eastern regions. This reinforces the perception of a Rockies "inland colony," where decisions made outside the region have a greater relative influence on land management and regional stakeholders than in other areas of the U.S.

Privately held forest lands are increasingly becoming part of the wildland–urban interface (WUI), where interspersed private development meets large tracts of public forest (see discussion below). The remainder of private forested lands is owned for multiple uses, including timber production, grazing, and conservation. Because federal agencies control the majority of forested lands in the Rockies, they will be the focus of this report. However, public land management practices can greatly influence nearby private forests, particularly with reagred to insect and disease infestation or fire risk.

Figure 1
Federal Land Ownership in the Rockies, 2005
Source: National Atlas of the United States

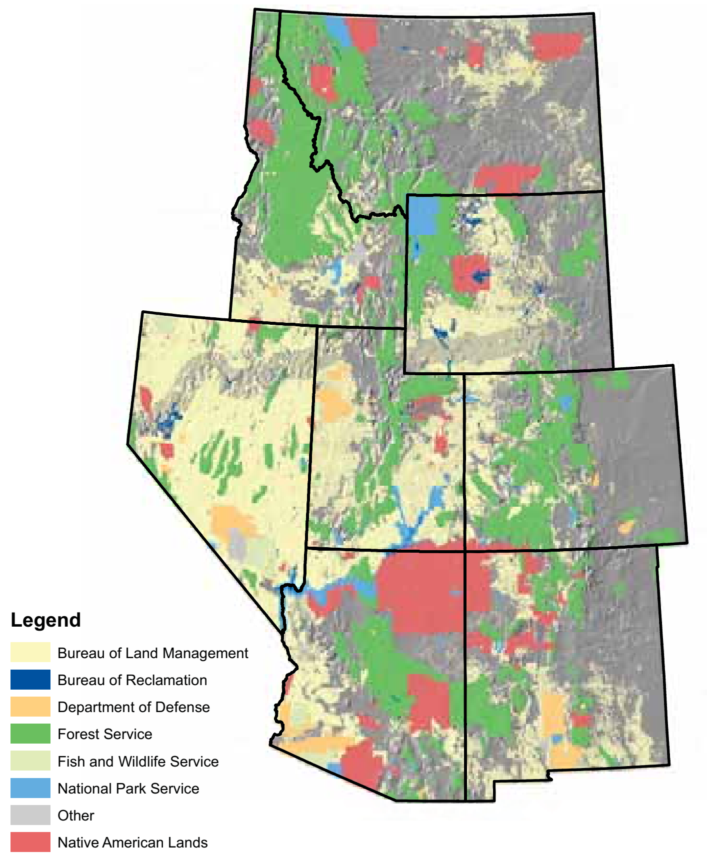


Table 1
Rockies Federal Land Ownership, Percent by State and Agency
Source: National Atlas of the United States

State	% Bureau of Land Management	%Bureau of Reclamation	%Department of Defense	%U.S. Forest Service	%U.S. Fish and Wildlife Service	%National Park Service	%Other	%Bureau of Indian Affairs	% of Total Land in Division
Arizona	17.2	0.2	3.9	16.2	2.2	3.4	0.0	27.3	70.4
Colorado	12.2	0.1	0.8	25.7	0.1	1.1	0.1	1.4	41.3
Idaho	21.8	0.2	0.4	40.4	0.2	0.9	1.2	3.3	68.5
Montana	8.1	0.1	0.3	19.9	1.1	1.3	0.1	8.9	39.8
Nevada	68.2	0.8	3.5	8.6	3.3	1.0	1.2	1.7	88.2
New Mexico	18.0	0.1	3.9	13.3	0.5	0.5	0.3	8.2	44.8
Utah	43.1	0.3	3.4	16.9	0.2	3.6	0.0	4.1	71.7
Wyoming	27.4	1.5	0.0	17.3	0.2	3.8	0.0	3.3	53.5
Rockies	25.8	0.4	2.0	19.1	1.0	1.9	0.3	7.8	58.4

Figure 2
Federal Land Ownership in the Rockies by State and Agency, 2005
Source: National Atlas of the United States

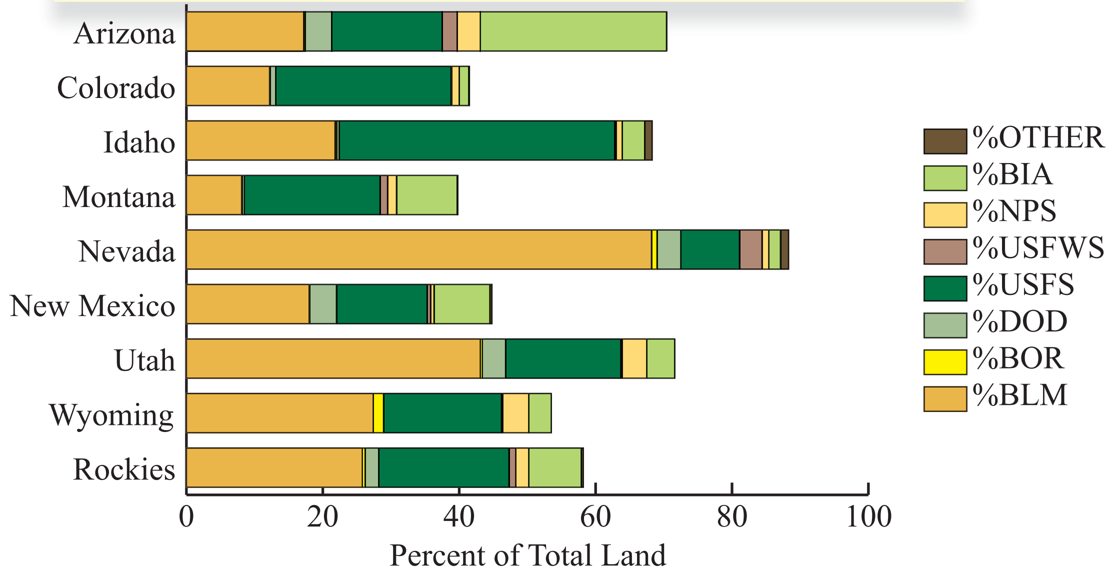


Figure 3
Federal Land Ownership by Agency and Census Division, 2005
Source: National Atlas of the United States

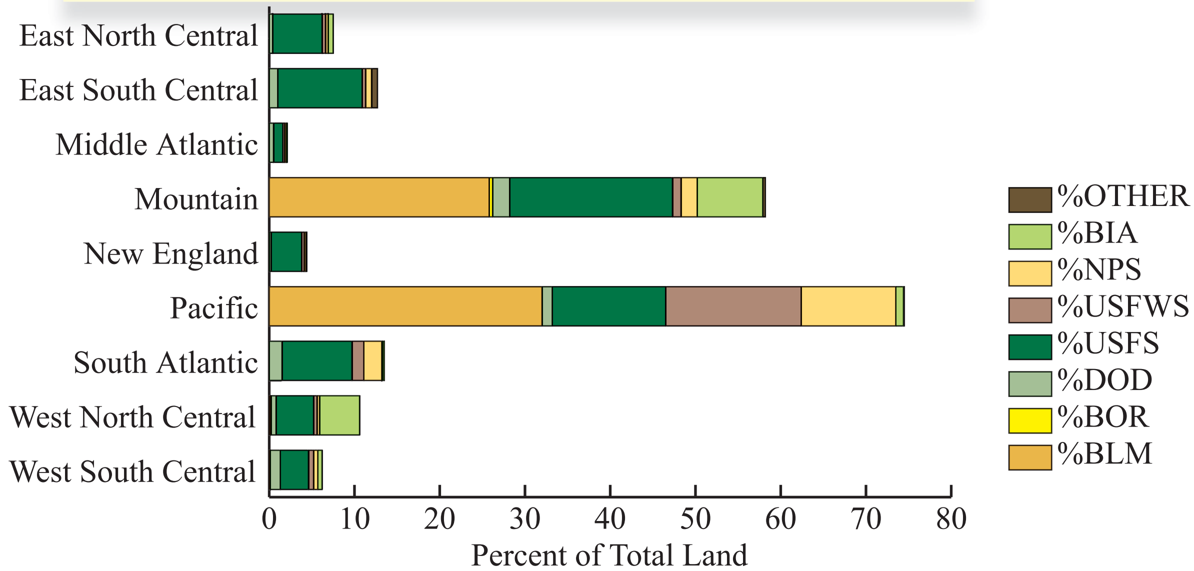


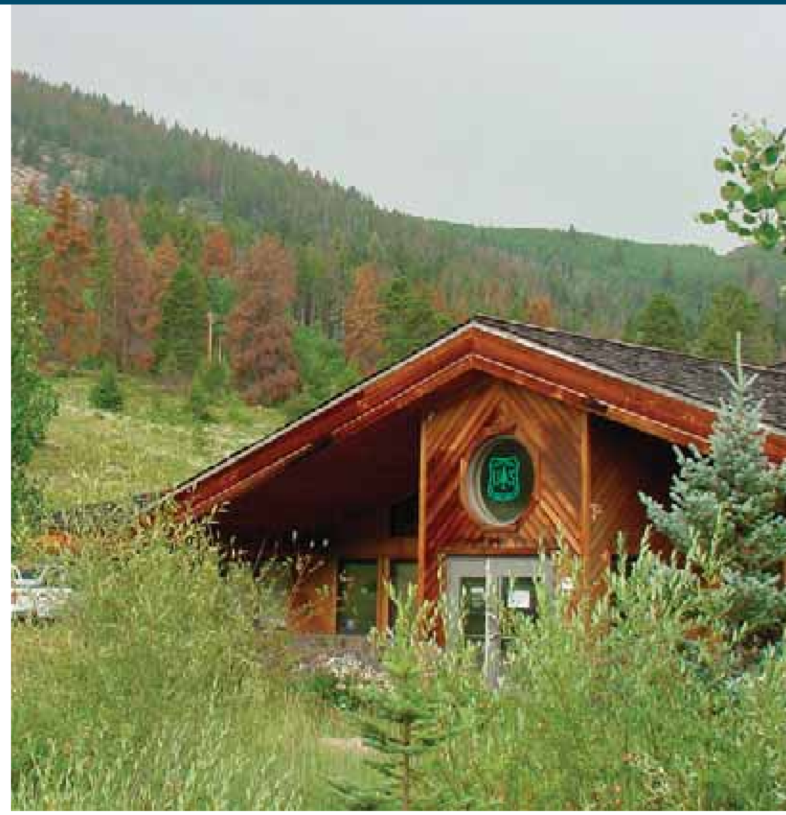
Table 2
Federal Land Ownership, Percent by Census Division and Agency
Source: Bureau of Economic Analysis, Regional Economic Information System

Census Division	% Bureau of Land Management	%Bureau of Reclamation	%Department of Defenses	%U.S. Forest Service	%U.S. Fish and Wildlife Service	%National Park Service	%Other	%Bureau of Indian Affairs	%of Total Land in Division
East North Central	0.0	0.0	0.4	5.8	0.4	0.3	0.0	0.6	7.4
East South Central	0.0	0.0	1.0	9.9	0.4	0.7	0.7	0.0	12.7
Middle Atlantic	0.0	0.0	0.5	1.1	0.2	0.2	0.0	0.1	2.2
Mountain	25.8	0.4	2.0	19.1	1.0	1.9	0.3	7.8	58.4
New England	0.0	0.0	0.2	3.6	0.3	0.2	0.0	0.1	4.4
Pacific	32.0	0.0	1.2	13.3	15.9	11.1	0.1	0.9	74.4
South Atlantic	0.0	0.0	1.5	8.2	1.4	2.1	0.2	0.1	13.4
West North Central	0.1	0.1	0.6	4.4	0.4	0.3	0.0	4.7	10.6
West South Central	0.1	0.0	1.2	3.3	0.6	0.5	0.0	0.5	6.2

Federal Land Managers and Legislation

The U.S. Forest Service was originally established as part of the Forest Reserve Act of 1891, which stated that "the President of the United States may, from time to time, set apart and reserve, in any State or Territory having public land bearing forests, in any part of the public lands wholly or in part covered with timber or undergrowth, whether of commercial value or not, as public reservations."[5] The associated Forest Service management goals were established in the Organic Act of 1897 with the aim of (1) improving and protecting the forest within the reservation; (2) securing adequate water flow; and (3) furnishing a continuous timber supply for the needs of U.S. citizens. However, the Organic Act does not authorize the inclusion of lands with valuable mineral deposits or agricultural fertility within the national forests.[6] Two primary resources shaped the Organic Act goals and the creation and management of the national forests between 1897 and 1960: water and timber.

With increased national interest in environmental protection and conservation in the 1960s, Congress responded with the Multiple Use Sustained Yield Act of 1960. The act states that the national forests shall be administered for multiple uses, including outdoor recreation, livestock grazing, timber sales, watershed protection, and wildlife management. Despite this multiple use strategy, the act does not affect the jurisdiction and responsibilities of individual states, stating that "nothing herein shall be construed as affecting the jurisdiction or responsibilities of the several States with respect to wildlife and fish on the national forests."[7] The 1960 act also does not change the management goals of the Organic Act (*i.e.*, the act supplements previous legislation). Most importantly, the Multiple Use Sustained Yield Act further requires that the relative values of the various resources be considered, not necessarily only the greatest dollar return or timber unit output.[8]



Minturn Ranger Station, Minturn, Colorado - June, 2006

Another protective measure for the national forests was provided by the Wilderness Act of 1964. "Wilderness areas" were to be secured as pristine forests where "the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain."[9] In these areas, no motorized equipment, permanent camps, or development are allowed.[10] This act also forbids mining, logging, and forest thinning within wilderness areas. Wilderness areas protected by the National Wilderness Preservation System increased from 9 million acres in 1964 to 105 million acres by 2005.

The National Forest Management Act of 1976 integrates the previous legislation and represents the primary statute governing forest management. The act requires the Secretary of Agriculture to assess forest lands, develop a management program based on multiple use, sustained yield principles, and implement a resource management plan for each national forest unit. Therefore, continual assessment of forest health is central to the U.S. Forest Service land management practices.

Despite the trend towards multiple use and sustained yield practices in National Forest system legislation, the Supreme Court ruled in the 1978 court case, United States v. New Mexico, that at least before the enactment of the Multiple Use and Sustained Yield Act of 1960, National Forests could only be created "to insure favorable conditions of water flow and to furnish a continuous supply of timber".[11]

Thus, according to federal case law, all forests established before 1960 must have as their primary goal either the protection of timber resources or watersheds. They may have secondary goals that follow the Multiple Use and Sustained Yield Act of 1960. The case does not rule on the four national forests established after 1960.[12,13]

In 2003, President Bush signed the Healthy Forest Restoration Act

(HFRA) into law. This legislation contains a number of provisions meant to hasten the preparation and execution of hazardous fuels reduction projects to lessen the risk of uncontrolled wildfires. More importantly, the HFRA allows fuels reduction projects, including those that use private logging companies to thin dense stands, to be exempt from some of the National Environmental Protection Act requirements.[14] This allowance for private logging is a point of contention. Critics of the HFRA suggest the law caters to the logging industry as it is not subject to the National Environmental Policy Act (NEPA) process.[15] Supporters claim the NEPA process is too costly and time-consuming to effectively manage against catastrophic fires, and the law maintains considerable oversight to adequately balance environmental and logging interests.[16]

The Bureau of Land Management

The Bureau of Land Management (BLM) is primarily responsible for range management and minerals development, established by historical precedent through the Mineral Leasing Act of 1920 and the Taylor Grazing Act of 1920 (originally administered by the U.S. Grazing Service). However, the BLM also manages 55 million acres of forests within the Western United States, including 11 million acres of commercial forests. Although the BLM is within the U.S. Department of Interior, it has similar policies to the USDA Forest Service with regard to sustainable yield practices. Many issues, programs, and policies affect both agencies. For these reasons, BLM and Forest Service lands are discussed together in this paper.

The Bureau of Indian Affairs

Native American lands within the U.S. also contain 18 million forested acres, managed by the Bureau of Indian Affairs (BIA) under the Secretary of the Interior.[17] Tribes must develop forest management plans, and such plans covered 85 percent of tribal forested acres as of 2005.[18] These plans include comprehensive management guidelines for tribal forest resources, providing revenues through forests that meet multiple use objectives.[19] Tribes have also launched aggressive management programs to reduce forest density and to salvage stands damaged by fire, insects, and disease.[20] However, these initiatives are currently under-funded. As noted by an Intertribal Timber Council report, “there is considerable risk that efforts to combat forest health problems and institute sustainable management for all [Indian] forest resources will be overwhelmed by a combination of funding shortfalls, personnel shortages, and ecosystem-based problems (insects, disease, and fire).”[21]

Bureau of Land Management policies usually help guide Native American forest land management in collaboration with tribal agencies. As previously stated, BLM policies are often similar to those of the U.S. Forest Service when addressing forest health issues, including fire, development, and disease. However, each federal agency does have distinct challenges and mandates.

Forest Ecosystems and Fire

Forest fires represent a key challenge for federal land managers. How can fire’s ecological services be balanced with human safety and economic interests in the Rockies? Fire’s role in natural forest ecosystems is first discussed, followed by historical fire management practices in the Rockies and the region’s current issues with fire management.

Fire is integral to the structure and health of forest ecosystems. Stand densities (the number of trees per area), species composition, median stand age, disease infestation, and natural succession all relate to fire conditions, notably the frequency and severity of fire events. Prior to the settling of the Rockies Region, fire served an important role in forest ecosystems,[22] removing saplings and providing space for larger, mature trees. Frequent, low-severity ground fires (known to foresters as a “nonlethal fire regime”) were common in ponderosa pine forests, leaving mature trees with their fire-adapted bark and removing ground litter and saplings. These fire events, occurring every 5 to 30 years, decreased competition among ponderosas for light, nutrients, and water and returned critical nutrients to the soil.[23]

In other forest ecosystems, the fire return interval is 100 to 400 years. These infrequent, high-intensity fires kill most, if not all, trees in the burned area. Foresters refer to these events as stand-replacement fires, and they are common in lodgepole pine, Engelmann spruce, piñon pine–juniper, Douglas fir, and subalpine fir forests.[24] Although individual trees do not survive stand-replacement fires, the ecosystem as a whole benefits from these events. Lodgepoles, for example, have two types of cones: serotinous (fire-loving) and non-serotinous. Serotinous cones do not open unless they are disturbed, most often by fire, but occasionally by animals or warmer soil temperatures. Following a fire event, the disturbed area is reseeded by lodgepole's serotinous cones.

One dramatic example of a stand-replacement lodgepole fire occurred in Yellowstone National Park in 1988.[25] Yellowstone is dominated by lodgepole pine forests that regenerated following multiple severe fires in the early 1700s.[26] An unusually dry year, combined with multiple natural and human-caused fires, resulted in a fire that burned for four months and affected 793,000 acres (36 percent of the total park area).[27] Fifteen years later, the site of the fires now attracts tourists with its wildflowers and young, regenerating lodgepoles.[28]

Intermediate between stand-replacement fires and nonlethal fires are mixed-severity fire regimes, comprised of individual fire events of variable intensity. These fires result in a patchy distribution of fire mortality and highly diverse forest communities, including mixed conifer species, Douglas fir, lodgepole pine, ponderosa pine, and riparian species.[29] Generally, mixed-severity fires kill a greater proportion of fire-susceptible, shade-tolerant species (subalpine fir) and leave a greater proportion of the fire-resistant species (western larch, ponderosa pine, western white pine, and whitebark pine).[30] Historically, approximately 50 percent of forests in the northern Rocky Mountains were formed through mixed-severity regimes.[31]

These generalized fire-regime categories (nonlethal, stand-replacement, and mixed-severity) are also affected by climate factors and their variability. Among these factors, moisture and temperature play key roles in shaping forests and fire regimes. When determining fire susceptibility, forest managers must consider whether precipitation falls evenly throughout the year or in certain seasons or months. For example, cooler temperatures throughout the spring can cause slow, sustained snow melt, decreasing the risk of fire. However, the heavier vegetation growth encouraged by such steady spring moisture may provide extra fuel if drier conditions prevail in the fall. Global weather fluctuations also affect Western forests. For example, El Niño/La Niña cycles can impact southwestern ponderosa pine forests. El Niño tends to bring greater precipitation to the southwest from the eastern Pacific; as noted above, this precipitation promotes understory growth that inhibits fire but may also create more fuel under later dry conditions. In contrast, La Niña events have resulted in dry winters, droughts, dry understory vegetation, and consequently greater fire risk in the southwest. Therefore, the general fire categories must also account for climate variability and the resulting changes in vegetation conditions.

The U.S. Forest Service and Fire Suppression

Although early observers of American forests noted the importance of fire to forest ecosystems, the Forest Service was charged with protecting timber reserves, which meant protecting forests from fires. Two of the first priorities of the Forest Service were to establish a firefighting infrastructure and secure a firefighting budget. Despite this original intent, the Great Fire of 1910 (also known as "The Big Burn" and "The Big Blowup"), fueled by strong winds and dry forests, burned 3 million acres of forests in northeast Washington, northern Idaho, and western Montana in just two days, killing 86 people. The newly established U.S. Forest Service responded strongly to the disaster, viewing fire suppression as the ultimate measure of forest conservation. By 1935 firefighting technology had improved, and the Forest Service proclaimed that its firefighters would extinguish all spotted fires by 10:00 AM the next morning.[32]

Opposite page: regeneration after the Yellowstone fire

Fire suppression both reduces soil nutrient turnover and results in unnaturally high stand densities throughout the Rocky Mountain region.[33] The Coconino National Forest in northern Arizona, known for its ponderosa pine forests, now averages stand densities of 851 trees per acre; prior to settlement this area averaged 23 trees per acre.[34] Ponderosa pine stands in Colorado's Front Range have increased from 40 to 50 trees per acre to 200 to 400 trees per acre in the last 30 years.[35] Dense tree stands are especially susceptible to intense, stand-replacement fires as flames can readily jump from one tree to the next. When a forest finally ignites after years of fire suppression, the fire intensity significantly increases.

Higher fire intensity generally results in more acres burned per fire started, whether by lightening, human carelessness, or arson. In 1910, more than 1700 fires were responsible for burning 3.1 million acres in the northern Rocky Mountains (1824 acres/start). However, in 2000, 78 fire starts burned more than 350,000 acres in the Bitterroot Valley of western Montana (4487 acres/start).[36] In an extreme event, Colorado's Hayman fire of 2002 was ignited by a single arson event and burned 138,000 acres (see Case Study 1: Hayman Fire).[37]

Current Fire Conditions in the Rockies

Given decades of fire suppression, how can forests return to their natural state, prior to extensive human intervention? To address this question, one must first determine which areas have departed from their natural range of variability in vegetation characteristics, fuel composition, and fire frequency/severity. Colorado's Front Range alone contains approximately 800,000 forested acres in this category.[38]

The current condition of forests in the Rockies can be measured by the Fire Regime Condition Class (FRCC), which ranks the departure of a landscape from the natural fire regime (i.e., a regime

Case Study 1: The Hayman Fire

The Hayman Fire was started by former U.S. Forest Service worker Terry Barton on June 8, 2002 and burned more than 138,000 acres within 20 days. Dry air over Colorado combined with 15 to 30 mph winds and the topography of the South Platte River to create perfect conditions for this catastrophic blaze. Despite an aggressive initial response, including the use of air tankers, helicopters, fire engines, and ground crews, firefighters could not contain the fire. In areas downwind from the Hayman ignition point, uninterrupted stands of trees with low crowns, shrubs, and a thick layer of pine needles covering the forest floor helped fuel the fire and hindered firefighting efforts.

The Hayman Fire engulfed areas that had undergone previous fuels treatments, including prescribed burns, thinning, and wildfires. Temperature and wind conditions on June 9, however, caused an intense surface fire that even overtook these treated areas, breaching massive expanses of them. Exceptions included the Polhemus prescribed burn (2001) and the area of the Platte Springs wildfire (2002), which stopped the fire locally. Fire behavior was modified but not stopped by stand thinning that had been conducted at the Manitou Experimental Forest. Road density did not appear to affect fire severity in any part of the Hayman Fire. In some areas, similar burn extents had not been seen in centuries. For instance, the burn around the Cheesman Reservoir was unprecedented in the past 700 years.

After the fire, post-fire rehabilitation treatments included hillslope treatments such as mulching, contour-felling of logs, and seeding, as well as channel treatments such as installing straw-bale check dams. The success of these treatments has not yet been determined; however, researchers at the Rocky Mountain Research Station caution that certain types of rehabilitation efforts (such as salvage logging, seeding, and soil scarification associated with treatments) may remove or diminish critical structures for wildlife that were created by the fire.

The Hayman Fire was the most expensive in Colorado history. The total cost, including property loss, loans and grants from the Small Business Administration and FEMA awarded in response to the fire, damage to electrical transmission lines, wildlife losses, and fire suppression costs and forest rehabilitation efforts, rose to over $237.82 million. The Hayman Fire illustrates the effects of long-term fire exclusion in the Rockies and suggests the ineffectiveness of certain types of small-scale treatments in reestablishing the historical fire regime.

Sources:

Huspeni, Dennis. Jury Will Weigh Hayman Fire Sentence.The Colorado Springs Gazette. January 18, 2006.
Russell T. Graham. Hayman Fire Case Study: Summary. U.S. Forest Service 2003.

Site of the 2002 Hayman Fire, as of July 2006

unaltered by modern human mechanical intervention).[39] These natural fire regimes have been classified into five categories which rank the frequency and severity of fires, ranging from Regime I (0–35 year frequency, low to mixed severity) to Regime V (200+ year frequency, stand-replacement fires).[40]

Condition Class III represents a high departure from an ecosystem's natural state. Under this classification, grasslands and shrublands exhibit high rates of encroachment and establishment by woody shrubs, trees, or invasive species. Forests exhibit elevated stand densities, encroachment of shade-tolerant tree species, and loss of shade-intolerant tree species.[41] Figure 4 shows the FRCC areas for the Rockies Region.

Once high-risk areas are identified, the appropriate management techniques for that particular ecosystem must be applied. A recent study explored FRCCs in the Rockies and recommended the following strategies:[42]

•Fire exclusion has had little to no effect on fuels or community structure in forests characterized by stand-replacement fires (*e.g.*, lodgepole pines). Therefore, restorative treatments are inappropriate in these forests, and reducing stand-replacement fires through forest thinning would alter their ecological roles. However, restoration could address other aspects of these ecosystems, such as native understory diversity which has been altered by human land-use practices.

•A combination of thinning and prescribed burning may be useful in restoring mixed-severity fire regimes (where ecological and fire-history data are sufficiently available). However, further research is required to prescribe or discourage treatment, given limited scientific understanding of these complex ecosystems.[43]

•Restoration of landscapes characterized by low-severity fires is ecologically appropriate and desirable. Thinning and prescribed burns are recommended techniques to restore stand densities to their historical range (prior to fire exclusion, grazing, logging, and plantation establishment). Retention of mature trees, large snags (standing dead trees), and downed logs is critical to restoring and maintaining ecological function in these ecosystems.[44]

The appropriate management technique is therefore strongly dependent on the ecosystem and how much human intervention has occurred. In many cases, little or no treatment is the best option.

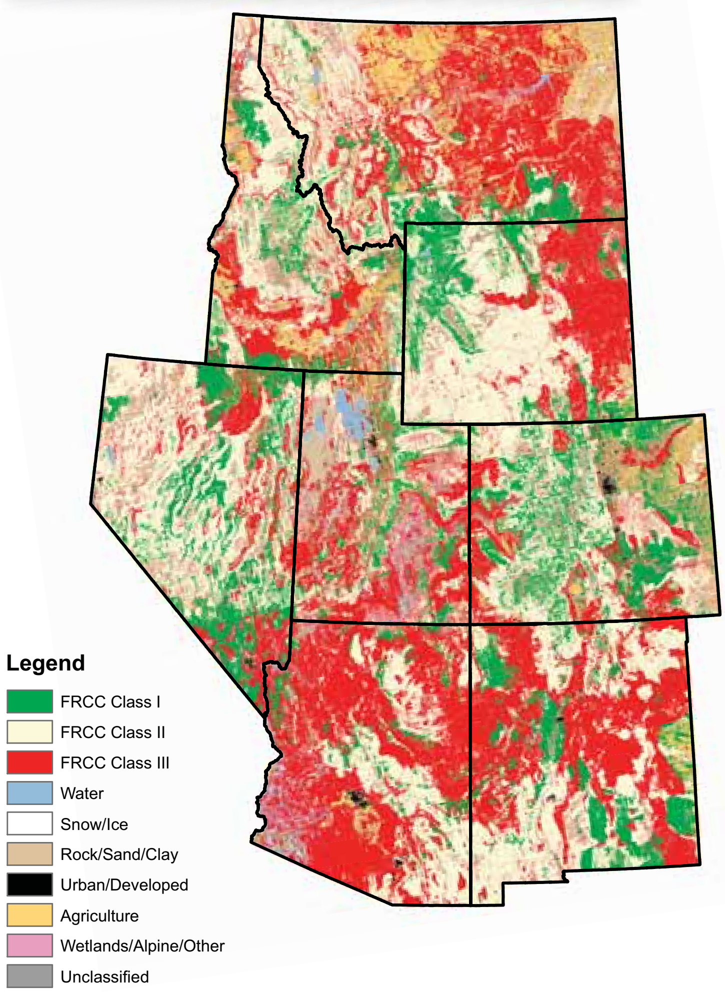
Insect and Disease Infestation in the Rockies

In addition to large forest fires, insect and disease infestations represent a second key factor affecting forest health. These infestations also exacerbate fire risk by killing mature overstory trees, providing readily burnable fuel for extensive canopy fires. Specific infestations affecting forest health in the Rockies Region include the mountain pine beetle, the piñon ips beetle, white pine blister rust, and heart-rot fungi. The extent of forest infestation in the Rockies is shown in Figure 5 and Tables 3 and 4, which rank the importance of these events in specific Rockies counties.[45] Counties are ranked according to the proportion of forests that are infested by disease and insects (Table 4) and the absolute acreage of diseased forests (Table 5); a 25 percent infestation level suggests which forests are likely to be greatly affected by a particular disease.

Mountain Pine Beetle

The mountain pine beetle, *Dendroctonus ponderosae*, attacks several pine species in the Rockies Region, particularly ponderosa, lodgepole, and limber pine. As of 2002, 4.1 million acres of forest were at risk from mountain pine beetle attacks in the United States, particularly in Colorado, Wyoming, Idaho, Montana, and Utah.[46]

Figure 4
Fire Regime Condition Class in the Rockies
Source: LANDFIRE Project, Wildland Fire Leadership Council



When mountain pine beetle infects its host tree, the tree releases sap to physically expel the beetle. However, trees that are stressed from drought, high stand densities, or large beetle populations cannot produce adequate sap to expel the invading beetles. Pioneer female beetles initiate the infestation, producing pheromones that then attract other beetles. After female beetles have invaded a tree, they construct vertical burrows in the phloem (vascular tissue that transports organic nutrients throughout the tree) in which they mate and deposit eggs. The beetle larvae develop inside the tree through the winter, feeding towards the bark until they emerge the following summer to invade other trees. The beetles in one infected lodgepole pine can infect four to seven new host trees the following summer.[47]

Pine beetles can introduce damaging bluestain fungus, *Ophiostoma minus*, to trees that they invade. Not all beetles carry the fungus, however, only two beetles are required to successfully infect a tree. The beetle's eggs carry the fungus that grows to fill the phloem and eventually the xylem (vascular tissue which transports water and inorganic ions up the tree). The result is nutrient and water loss and inadequate pitch to expel invading beetles. The tree eventually starves to death, its needles becoming red and dry.[48]

Recent mountain pine beetle outbreaks are likely enhanced by warmer temperatures and increased drought. Extreme cold is necessary to kill mountain pine beetle populations; winter air temperatures must drop to -40ºF for several hours or -30 to -35ºF for several weeks;[49] spring or fall cold spells can also stop the beetle

Figure 5
Forest Disease Risk in the Rockies
Source: Unpublished data generously provided by Frank Krist, Frank Sapio, and Borys Tkacz, U.S. Forest Service

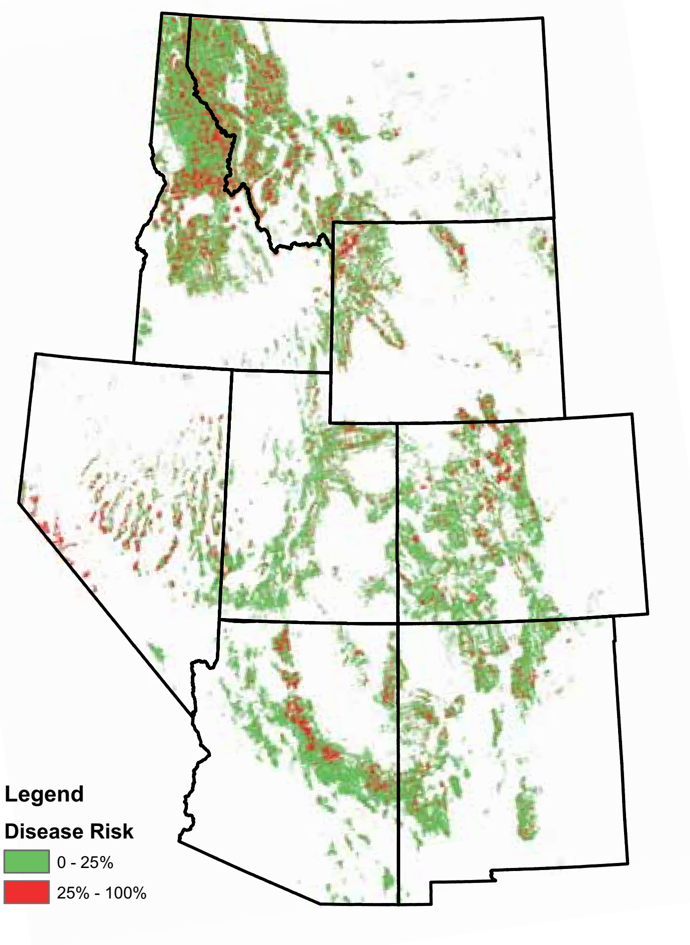


Table 3
Forest Disease Top Ten, Relative Acres by County
Source: Unpublished data generously provided by Frank Krist, Frank Sapio, and Borys Tkacz, U.S. Forest Service

County, State	%Diseased	Rank
Lyon, NV	81.9	1
Mineral, NV	66.5	2
Storey, NV	55.4	3
Esmeralda, NV	55.1	4
Douglas, NV	40.0	5
Carson City, NV	31.3	6
Churchill, NV	31.3	7
Nye, NV	29.0	8
Sheridan, WY	28.0	9
Lander, NV	26.0	10

Table 4
Forest Disease Top Ten, Absolute Acres by County
Source: Unpublished data generously provided by Frank Krist, Frank Sapio, and Borys Tkacz, U.S. Forest Service

County, State	Healthy Acres	Diseased Acres	Rank
Idaho, ID	2,3071,820	1,418,843	1
Coconino, AZ	9,736,496	994,528	2
Nye, NV	1,507,716	614,445	3
Flathead, MT	1,8321,596	530,418	4
Teton, WY	4,903,880	515,213	5
Sanders, MT	18,294,456	440,973	6
Shoshone, ID	18,281,844	440,745	7
Mineral, MT	18,286,349	437,917	8
Ravalli, MT	18,601,228	436,099	9
Missoula, MT	18,302,978	434,220	10

but must bring temperatures of around -25ºF.[50] The beetles' reproductive rate also increases with increased temperatures.[51] Most importantly, increased temperatures open previously unoccupied, healthy habitats to the mountain pine beetle at higher latitudes and altitudes, including lodgepole and jack pine ecosystems.[52]

Mountain pine beetle infestations may also increase fire risk.[53] The year following a beetle kill, the abundance of dead pine needles in the tree crown increases fire risk and the development of crown fires. After three to five years, however, the dead needles fall to the ground, reducing the canopy fire risk. Decades later, these dead, bare trees eventually fall to the ground, serving as fuels that promote high-temperature, stand-replacement wildfires. Such fires burn the forest floor, ladder fuels, and the newly regenerated canopy.[54] These intense fires can also sterilize the soil (*i.e.*, all nutrients and organic matter are burned out of the soil); the complete loss of vegetation increases the risk of soil erosion and the establishment of invasive species.

Natural controls on the mountain pine beetle population are presently not effective over large regions. The frigid temperatures needed to kill beetle larvae are unlikely given future climate predictions. Beetle predation by woodpeckers generally results in 20 percent beetle mortality, but 99 percent mortality is required to stop the infestation (other predators include checker beetles, ostomid beetles, and the fly *Dalla chapodidee*).[55] Although woodpecker populations have responded to the mountain pine beetle infestation, the beetle outlasts predators by overwhelming and satiating them. A third natural control on the mountain pine beetle population is food and habitat availability. Forest destruction caused by fires and by the beetles themselves may eventually limit the extent of beetle habitat. Given the scale of the mountain pine beetle epidemic, limited habitat may be the best available control on the exploding populations.

Human controls on the beetle population include pesticide spraying and forest thinning. Representatives John T. Salazar and Mark Udall of Colorado have introduced an act to amend the Healthy Forests Restoration Act. The act, called the Rocky Mountain Forest Insects Response Enhancement and Support Act, or the "Rocky Mountain FIRES Act," allows land managers in insect-infested areas to apply for fuels-treatment funding through the Community Wildfire Protection Plan. This act would also direct $25 million ($5 million over five years) to help communities develop a required Community Wildfire Protection Plan, funded by onshore oil and gas development royalties. Finally, the act would exclude projects within the Healthy Forests Restoration Act from the National Environmental Policy Act (NEPA), including proposed mountain pine beetle impact studies. This exclusion would limit, if not eliminate, obligations to conduct Environmental Impact Statements.[56] Opponents of this legislation argue that the current beetle infestation levels are not ecologically anomalous, do not increase the risk of crown fires, and do not warrant relaxed NEPA regulations.[57]

The Piñon Ips Beetle

The Piñon ips beetle, *Ips confusus*, is another important beetle in the Rockies. The ips beetle, also known as the pine engraver beetle, has killed piñon pine trees in over 60,000 square miles of piñon–juniper woodland in the Four Corners Region, and the total piñon mortality in this area is estimated to be 25 percent.[58] These beetles affect several other pine species as well, including lodgepole and ponderosa pines. Like the mountain pine beetle, ips beetle larvae feed on the tree phloem, just under the bark. However, the ips beetle eventually kills the infected tree by girdling it, not by a fungal infection.

The piñon ips beetle is endemic to the desert southwest, yet the current tree mortality level is unprecedented. Scientists hypothesize that recent extreme droughts and rising temperatures have resulted in weaker, stressed trees. High stand densities also promote the movement of ips beetles from one infected tree to its uninfected neighbors. Few solutions exist to reduce the severity of these outbreaks, although expensive chemical treatments ($10–$45 per tree) have been completed in high-value areas such as around park and forest visitor centers. Thinning also increases piñon pine vigor and the remaining, more vigorous trees can better pitch out beetles.[59]

Heart-Rot Fungus

The heart-rot fungus, *Phellinus tremulae*, infects the heartwood of aspen trees in the Rockies. The infection mechanism is not well understood, but the Forest Service hypothesizes the fungus reaches interior heartwood through dead branch stubs and fresh wounds.[60] The fungus will attack the tree's heartwood until it is entirely decomposed. This decomposition can benefit ecosystems by creating gaps in forest canopies that enhance succession and biodiversity, creating critical habitat for cavity-nesting birds and facilitating nutrient cycling.[61] Heart-rot fungus might also mitigate other insect infestations, as many cavity-nesting birds are insectivores. However, the heart-rot fungus greatly reduces, if not eliminates, the timber value of aspen.[62] In this case, forest managers must balance ecosystem health and timber production.

White Pine Blister Rust

White pine blister rust, *Cronartium ribicola*, is present in numerous areas throughout the Rockies, including Yellowstone National Park. An invasive fungus originating in Asia, white pine blister rust is likely the most destructive white pine disease in the United States. Hosts include whitebark pine, western white pine, limber pine, and southwestern white pine. The disease is exacerbated by extended cool, moist conditions during late summer and early fall. The ecological impacts are significant, as this disease threatens to eliminate white pine species in Western ecosystems.[63]

Population Growth and Fire Management

A third critical factor affecting forest health in the Rockies is recent development by humans, particularly the growth of urban areas near national forests and interspersed housing within forested areas. The high population growth in the Rockies reflects the abundant natural and recreational amenities of this region, but new residents may not be aware of the risks they pose to nearby forests.

One useful measure of human–forest interaction is the growing area of wildland–urban interface (WUI), defined as a wildland area within a half mile of housing with densities greater than 1 house per 40 acres.[64] This area is expected to double in the next 20 years. In Colorado's Front Range alone, there are 1.1 million WUI acres in which fire risk mitigation is necessary to protect human life, property, and other assets (*e.g.*, watersheds, wildlife habitats, and community infrastructure). Figure 7 shows the WUI areas of the Rockies Region.

Possible solutions to increased fire risk include buffer zones, prescribed burns, and forest thinning (see Case Study 2: Idaho Wildland Fire Use Fires). Buffer zones provide an effective solution to fire risk by removing fuels from areas of human life and property. Prescribed burns may reduce fire risk by eliminating ground and ladder fuels and restoring forests to their historical range of variability. However, prescribed burns are often inappropriate in the wildland–urban interface, as unforeseen wind conditions or fire

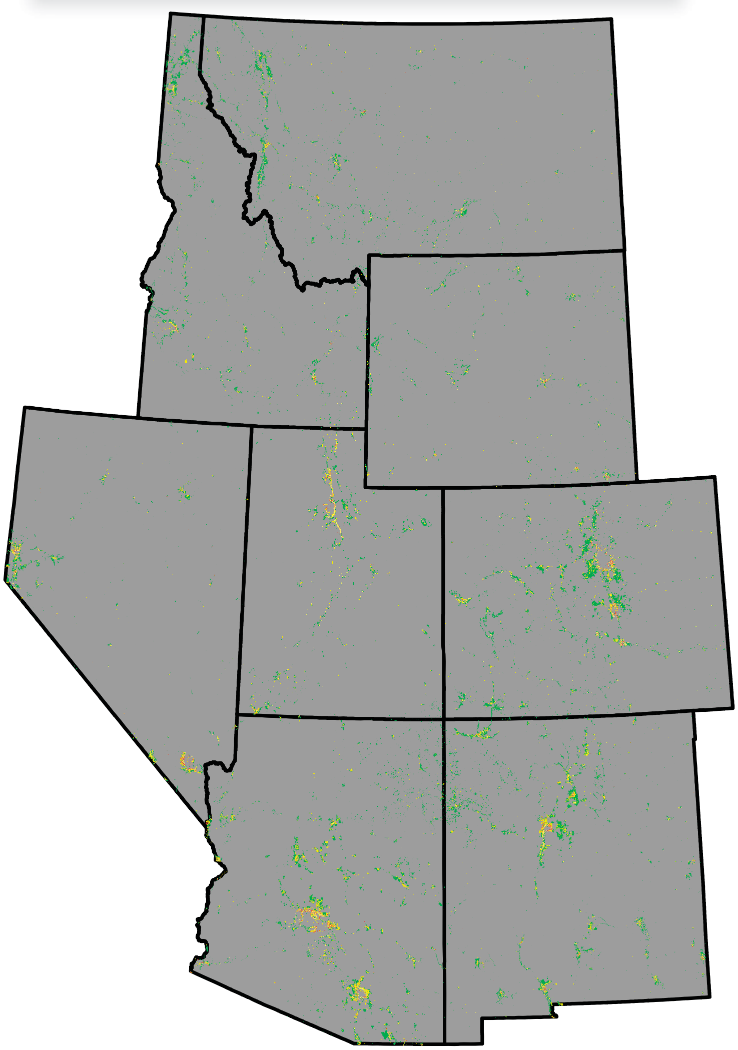
behavior can place lives and property at risk (see Case Study 3: Cerro-Grande Prescribed Fire and Wildfire).

Another solution actively pursued in WUI areas is forest thinning (see Case Study 4: Vail Valley Forest Health Project). Forest thinning projects can also target invasive species that are often associated with human development and can rapidly spread through burned areas.[65] According to the Front Range Fuels Treatment Partnership, "treatment plans should avoid the creation of sterile, park-like forests that have evenly-spaced trees and no shrubs or downed logs. Instead, treatments should achieve a complex mosaic of forest structures with patches of variable tree densities and ages that favor retention of the older trees."[66] By retaining part of the understory and the forest canopy, the introduction of invasive species can be minimized.

A concern of forest thinning is the fate of the small-diameter, low market value trees harvested from dense stands. One possible use of these timber products is as biomass fuel, providing energy for local schools and municipal buildings. For example, the city of Nederland, Colorado uses thinned trees to fire a 20 horsepower boiler, generating 5 million BTUs per hour to heat the Nederland Community Center.[67] Another use of small-diameter timber is niche market products such as timber flooring and furniture (see Case Study 5: North Slope Sustainable Wood, LLC).

The intersection of WUI areas and high fire risk is one regional measure of fire risk by county (that is, showing where people and fire risk coincide). We compared WUI areas (low, medium, and

Figure 7
The Wildland Urban Interface in the Rockies
Source: SILVIS Lab, Forest Ecology and Management System
University of Wisconsin-Madison



Case Study 2: Idaho Wildland Fire Use Fires

Wildland fire use is the practice of allowing naturally ignited fires in areas where fire is a major component of the ecosystem to burn. These fires are closely monitored and managed by the Forest Service. Traditionally, the Forest Service only allowed WFU in wilderness areas. However, Chuck Mark, the district ranger for the St. Joe Ranger District in the Idaho Panhandle National Forest, began a program utilizing WFU in Roadless areas in 2000.

The effects of wildfires in 1960 can still be seen in this area, where extensive brush fields cover areas where trees have not yet regrown. The intensity of these fires may have sterilized the soil, killing all trees as well as their seeds. These devastating effects made many in the public sector as well as the Forest Service reluctant to expand the use of WFU. However, Mark championed this program, arguing that the best way to help a landscape suffering from fire exclusion is to allow lightening-ignited fires to burn. Further, he contended that thinning programs will never be economically feasible because in many cases valuable timber has already been harvested.

Allowing naturally ignited fires to burn is a less expensive, yet more hazardous (if the fires get out of control), alternative to forest thinning. The WFU program attempts to return landscapes to their natural range of variability.If Mark's program is successful, it may be expanded throughout the Rockies Region to include other roadless areas and possibly national forests outside wildland–urban interface areas.

Sources:
Chuck Mark. District Ranger, St. Joe Ranger District, interview by author, 02 August 2006.
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Case Study 3: Cerro-Grande Prescribed Fire and Wildfire

The Cerro Grande Prescribed Fire was ignited as part of an approved plan on May 4, 2000 by fire personnel at Bandolier National Monument. Sporadic wind changes caused spotting (fires outside the fire perimeter caused by wind-carried burning branches or leaves) and "slopover" on the eastern fire line. Slopover occurs when fires spread outside the boundaries of a control line such as that created by a previous burn, firebreak, or line of fire personnel.

The fire was declared a wildfire at 1 PM on May 5. It was then contained for approximately 24 hours before a significant increase in winds from the west. The fire moved out of control to the east at the Santa Fe National Forest. At its most severe, the Cerro Grande Prescribed Fire produced spotting over a mile across fire lines in all directions. The fire began to move toward the towns of Los Alamos and White Rock, where 18,000 residents were evacuated. By May 10, the fire had destroyed 235 homes.

The Interagency Fire Investigation Team formed by Secretary of the Interior Bruce Babbitt concluded that federal personnel had failed to properly plan and implement the Cerro Grande Prescribed Fire. The investigators maintained that the Federal Wildland Fire Policy is sound yet depends on strict adherence to proper implementation by every agency involved. Although prescribed fires are a viable method of restoring landscapes to their historical fire regimes, public acceptance of this method is important. Prescribed fires that turn into wildfires have had harmful consequences not only in terms of property and costs, but in terms of public perception.

Source:
National Park Service"Cerro Grande Prescribed Fire Investigation Executive Summary." http://www.nps.gov/cerrogrande/executive_summary.htm (2000)

high interface and intermix areas) to the fire risk condition class III category. The number of acres for each WUI category was then determined, weighted according to each category, and assigned a final rank.[68] The result is shown in Table 5 for the top ten counties, as determined by our method. Seven Arizona counties ranked in the top ten (Maricopa, Pima, Pinal, Navajo, Coconino, Mohave, and Yavapai), with Clark (Nevada), Santa Fe (New Mexico), and El Paso (Colorado) counties also identified as high fire risk areas.

Legal and Scientific Debates: Roads and Salvage Logging

Solutions to regional forest health issues, such as fire, infestation, and development require a realistic assessment of existing resources, projected costs, and agreement on forest management plans among interested parties. However, agreement can be difficult to obtain, especially when mixing politics, science, and different visions for our national forests. Two key debates relate to road development in currently roadless areas and the practice of salvage logging.

The Roadless Rule

In 2001, the Roadless Area Conservation Rule was established to prohibit road construction and reconstruction in 59 million acres of inventoried National Forest areas. These areas were defined as undeveloped areas exceeding 5,000 acres. The "Roadless Rule" prohibited most timber harvests in inventoried roadless areas; exceptions included those areas that reduced fire risk, improved wildlife habitat for endangered, proposed (for listing as endangered), or sensitive species, and maintained or restored ecosystem composition and structure.[69]

Roadless areas present challenges to forest management. Transport of the heavy equipment required for forest thinning, including hydro-axes, bulldozers, and chippers, often requires an extensive road network, although small-scale thinning can be accomplished by work teams and pile burning. Without adequate thinning, many forest ecosystems may experience insect infestations or crown fires. However, many forest experts consider the current fire and disease regime part of a natural cycle, best left to nature rather than work teams. Environmental groups also argue that roads fragment wildlife habitat and cause soil erosion. One study has found that roads fragment forest ecosystems more than clearcutting by dissecting large, contiguous regions into smaller pieces and converting the forest interior into a series of edge habitats.[70]

In 2005, the Roadless Rule was repealed by the Bush administration, re-opening 59 million areas for road development. This

Table 5
Fire Risk Top Ten, Absolute Acres by County

County, State	Minimum	Medium	Maximum	Rank
Maricopa, AZ	130,694	81,295	12,161	1
Clark, NV	38,192	32,080	11,160	2
Pima, AZ	118,995	68,983	5,473	3
Pinal, AZ	49,804	24,822	2,631	4
Navajo, AZ	88,684	18,781	729	5
Santa Fe, NM	78,344	17,554	913	6
Coconino, AZ	70,852	16,342	1,106	7
Mohave, AZ	52,235	20,730	1,015	8
Yavapai, AZ	52,980	14,599	1,146	9
El Paso, CO	46,861	15,837	1,083	10

Case Study 4: Vail Valley Forest Health Project

The Vail Valley Forest Health Project (VVFH project) was created in response to the mountain pine beetle infestation outbreak in the Vail Valley of Eagle County, Colorado. The outbreak, which began in 1996, killed approximately 20,000 trees in the year 2000 alone, and the Forest Service has identified Eagle County as having the third highest level of mountain pine beetle infestation in Colorado. Fire suppression in the area over the past 60 years has created ideal conditions for the mountain pine beetle: evenly aged, dense lodgepole pine stands with decreasing aspen populations.

The VVFH project began in 2001 when the Forest Service entered into a participating agreement with the town of Vail. This agreement involves a $730,000 commitment by Vail to fund the Forest Health project. The town also agreed to provide technical assistance, fund salaries for town personnel assigned to prescribed burn activities, and monitor post-fire treatment response. A Final Environmental Impact Statement (FEIS) was issued in 2003, followed by a Record of Decision (ROD) in 2006. Forest Service personnel from the White River National Forest branch decided on a plan that will encompass 3,000 acres of national forest lands.

South of the I-70 corridor, about 700 acres of lodgepole pine will be thinned, chemically treated, salvaged, or patch cut. The remainder of the project will involve approximately 700 acres of aspen, which will be treated through patch cuts, perimeter treatments, and prescribed burning. North of the I-70 corridor, 1,600 acres of shrublands, grasslands, and aspen will be managed to return them to their historical range of variability (HRV). Mechanical vegetation treatments and prescribed burning will be used to vary stand age and density such that the potential intensity and severity of wildand fires in the wildland–urban interface will be reduced.

As of August 2006, the Forest Service had thinned 1,800 acres at a cost of $115,000. Cutting alone costs approximately $600 per acre, while piling and burning cut material that cannot be hauled away raises the cost to about $1,800 per acre. This case from the Vail Valley provides an example of community–Forest Service partnership that other municipalities and areas may want to follow in seeking ways to mitigate beetle infestations.

Sources:
USDA Forest Service, White River National Forest, Holy Cross Ranger District and Town of Vail. Participating Agreement. 2006.
USDA Forest Service, White River National Forest, Holy Cross Ranger District. Vail Valley Forest Health Project 2006.
Phil Bowden. Wildland Fuels Management Specialist Upper Colorado River Fire Management Unit USDA-FS/USDI-BLM, interview by author, 17 July 2006.
Cary Greene. Wildland Fuels Management Specialist Upper Colorado River Fire Management Unit USDA-FS/USDI-BLM, interview by author, 17 July 2006.

repeal addressed motorized access to the National Forests, citing inadequate public access to the roadless areas (i.e., no vehicles, no people). A limited rebuttal process does exist: proposed changes to specific roadless areas can be petitioned by state governors and filed with the Department of Agriculture. These petitions are not binding, and the Department of Agriculture can accept, modify, or reject them.[71]

The 2001 Roadless Rule was reinstated on September 20, 2006 by US Magistrate Judge Elizabeth Laporte of the United States District Court for the Northern District of California.[72] Laporte ruled that the Bush Administration violated the National Environmental Policy Act and the Endangered Species Act when it repealed the Roadless Area Conservation Rule.[73] Both New Mexico and Montana were co-plaintiffs in this four-state lawsuit to reinstate the 2001 Roadless Rule.[74] Following this ruling, the Chief of the Forest Service prohibited any "further management activities in inventoried roadless areas that would be prohibited by the 2001 Roadless Rule".[75]

Salvage Logging

Salvage logging, where dead trees are removed from a diseased or damaged area, is another issue currently under debate by politicians, scientists, and the public. Following a mountain pine beetle attack, trees can be harvested for approximately five years (mortality caused by the bluestain fungus does not affect a tree's structural integrity during this timeframe). After five years, however, the tree begins to "check": the wood is cracked by multiple freeze–thaw cycles and drying. Once cracked through the trunk, the tree is no longer valuable for timber.[76]


Widespread "beetle kill" in the Wildland Urban Interface, Vail, CO July, 2006

In response to the loss of harvestable timber caused by infestation and fire, Representative Greg Walden of Oregon has introduced the Salvage Logging Bill. The goal of the bill is to implement recovery treatments in response to catastrophic events, as determined by the Secretary of the Interior (BIA, BLM) and the Secretary of Agriculture (USFS). This includes the removal of dead and damaged trees and the implementation of reforestation treatments.[77]

The bill requires the Secretary of the Interior and the Secretary of Agriculture to develop a list of pre-approved management practices

by forest type that may be implemented as part of recovery projects. Because these pre-approved practices will be deemed emergency procedures, they must only consider the management practices and the "do-nothing" alternative when conducting an Environmental Impact Statement. Furthermore, the secretaries are permitted to use emergency procedures to circumvent the Endangered Species Act, excusing them from "incidental takings" of endangered species.[78]

In support of the bill, Mark Rey, Undersecretary of Agriculture for Natural Resources and Environment, argued that "in many cases, active management can restore a forest faster than letting nature take its course."[79] However, in August 2006, 500 scientists from academic and private institutions contested this view, asking Congress to defeat this legislation in favor of a more science-driven approach. They argue that:

> *Post-disturbance logging impedes regeneration of forest landscapes when it compacts soils, removes or destroys so-called biological legacies (such as soil organic material, seeds in the soil, large standing and downed trees) damages riparian corridors, introduces or spreads invasive species, causes erosion, delivers sediment to streams from logging roads and steep slopes, degrades water quality, and damages populations of many aquatic species.*[80]

A recent study also asserts that post-fire logging destroys much of whatever natural tree regeneration is occurring and generates significant short- to mid-term increases in fine and medium fuels (which may increase the re-burn potential).[81] The study also argues that post-fire logging taxes the public treasury, citing Oregon's Bis-

Case Study 5: North Slope Sustainable Wood, LLC

Fifteen years ago, Peter Stark bought 80 acres of forested land on the outskirts of Missoula, Montana, abutting the Rattlesnake Mountains. After taking a state-sponsored workshop that taught private landowners to develop a "forest stewardship plan," Stark realized that his forests were in poor shape. They had been clear-cut about 100 years ago and had grown back in a thick mat of Douglas fir and larch that had escaped much-needed thinning. Stand densities were over 830 trees per acre and despite being about a century old, most trees were only eight inches in diameter. The growth rings in the trees were so close together that it took a magnifying glass to see them.

Wishing to restore his forest, Stark enlisted the help of restoration forester Matt Arno. Matt Arno holds a degree in forestry and founded Montana-based Woodland Restoration, Inc., a timber company that harvests with the goal of restoring forest health. Although Arno occasionally worked on a break-even basis, accepting the thinned logs as payment, Stark's steeply graded land did not allow this. The two held off for years, searching for an economical use for Stark's timber. They found that use when Stark and his wife Amy decided to build a dance studio and office. The high price of flooring revealed a potential use for their thinned larch trees. Amy Stark's dance floor became the first floor created by North Slope Sustainable Wood, LLC.

The company produced 22,000 square feet of small-diameter timber flooring in 2002 alone and has been in business for four years. Private landowners hire Matt Arno to restore their forests; Arno then sells these logs to a sawmill where they are made into tongue-and-groove flooring. Stark buys these floorboards and installs them for his customers.

Stark's and Arno's flooring uses a previously difficult-to-market good (small-diameter timber). They anticipate that the revenue they generate will allow the forest service to save almost $400 per acre in treatment costs if they hire North Slope Sustainable Wood, LLC and Woodland Restoration, Inc. to perform forest treatments. They further estimate that over the next 15 years, if they are awarded a Woody Biomass Utilization Grant through the Healthy Forests Restoration Act, they will be able to restore approximately 22,000 acres of land (both public and private).

Although it is rare to come across business ventures that profitably use small-diameter timber harvested as part of forest restoration, this approach to forest treatment is well suited for wildland–urban interfaces because unlike prescribed burning it does not pose a threat to life and property.

Sources:
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Peter Stark. interview by author, 27 July 2006.

cuit Fire of 2002 as an example (post-fire logging operations exceeded revenue by $14 million). Therefore, salvage logging might not provide the best long-term, economically viable solution to forest management in the Rockies.

Conclusion

Healthy forests are an important challenge for the Rockies Region. Visitors and new residents flock to this area for clean air, recreational amenities, pure water, and scenic beauty provided by the national forests. Disease and fire cycles threaten not only these features but also human safety and property. The 1988 Yellowstone National Park fire showed that forests will regenerate and this process too can be both healthy for the forest and a draw for visitors. However, the immediate economic costs of devastated forests are potentially enormous to regional tourism, land developers, and natural ecosystems (*e.g.*, watersheds and soils). The debate for the next century will center on the "greatest good" provided by the national forests and the most appropriate management strategies. Most importantly, the people of the Rockies should provide a strong voice in this debate, as these decisions will affect the familiar, pristine corners of our backyard.

Endnotes

[1]Calculated from U.S. Forest Service Wildland Fire and Fuel Management data, http://www.fs.fed.us/fire/fuelman/. The forest area here includes the following ecosystems: desert shrub, other shrub, elm–ash–cottonwood, aspen–birch, western hardwoods, ponderosa pine, Douglas fir, larch, western white pine, lodgepole pine, western fir–spruce, pinon–juniper, and alpine tundra.
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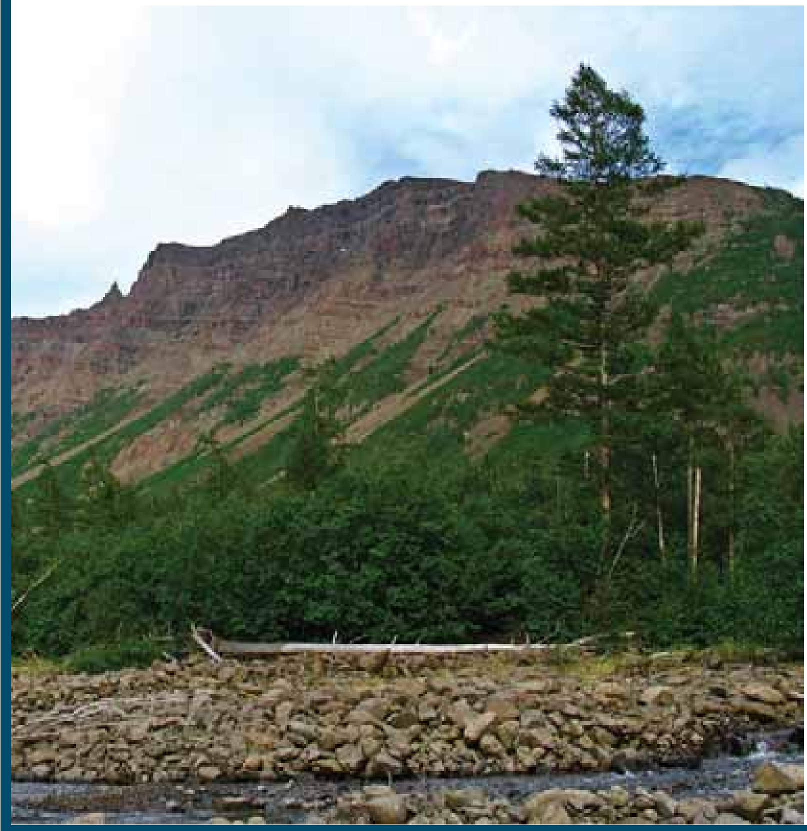
[7]16 U.S.C. § 528–531.
[8]*Ibid*.
[9]16 U.S.C. § 1131 (c).
[10]16 U.S.C. § 1133 (c).



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[12]U.S. v N.M., 438 U.S. 696, 715 (1978).
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[24]*Ibid*. p. 80–87.
[25]Merrill K. Kaufmann. *Emeritus Research Forest Ecologist U.S. Forest Service Rocky Mountain Research Station*. Interview by author, Fort Collins, Colorado, 10 July 2006.
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