

## HAYMAN FIRE RESEARCH SUMMARY, 2003-2012



Photos: Merrill Kaufmann (top, in 2002) and Paula Fornwalt (bottom, in 2010)

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## Introduction

The Hayman Fire ignited on Saturday, June 8, 2002 near Lake George, Colorado. The fire spread rapidly northeastward down the South Platte River corridor, driven by strong southwesterly winds exceeding 50 miles-per-hour. Although the initial attack was very aggressive, the hot, fast winds combined with bone-dry fuels to produce major runs during the first few days of the burn. There was prolific torching and spotting, making control a near-impossible task. Within 48 hours of ignition, the fire grew to over 60,000 acres. By the time the fire was declared to be under control on July 18, the fire had burned nearly 138,000 acres (about 215 square miles) (Graham 2003).

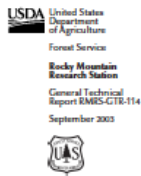


Smoke plume from the Hayman Fire (Photo: USDA Forest Service)

The Hayman Fire was Colorado's largest wildfire in recorded history and was widely viewed as being uncharacteristic in its size and severity for the lower

elevation Ponderosa pine zone. Because of its size and the proximity to the Denver metropolitan area, the Hayman Fire attracted intense interest locally and nationally.

In the time since the fire, precipitation events have resulted in massive soil erosion and dumped enormous quantities of sediment into Denver Water's reservoirs and intake systems. The domestic water supplier to the City of Denver has expended millions of dollars in sediment treatment, with costs still mounting to this day to mitigate sediment loads. The uncharacteristic size and severity of the fire also raise questions about what happened during and after the fire. What influenced the fire's behavior? What happened to the soils? What kind plant life would recolonize and spread through the burned area? How would wildlife fare?



## Hayman Fire Case Study

Russell T. Graham, Technical Editor



Following the Hayman Fire, a comprehensive study (Graham 2003) was published by the USDA Forest Service's Rocky Mountain Research Station.<sup>1</sup> Involving over 60 research scientists and resource professionals, the report covers the following topics:

- Fire behavior, fuel treatments, and fire suppression
- Ecological effects – fire regimes,

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<sup>1</sup> Available for viewing and downloading at:  
[http://www.fs.fed.us/rm/pubs/rmrs\\_gtr114.html](http://www.fs.fed.us/rm/pubs/rmrs_gtr114.html)

historic forest and landscape structure, soils, aquatic ecosystems, forest succession, invasive non-native plants, and species-of-concern

- Home destruction
- Post-fire rehabilitation
- Social and economic issues

Since the 2003 case study report, further research has been conducted. This report summarizes key findings from scientific research conducted since the Hayman Fire, focusing on six topic areas:

- Fire behavior, fuel treatments, fire weather, and smoke
- Wildlife
- Plants
- Soils
- Water
- Socio-economics

This report coincides with the 10-year anniversary of the Hayman Fire and was prepared for distribution at the Hayman Science Symposium, June 21-22, 2012.

## **Fire Behavior, Fuel Treatments, Fire Weather, and Smoke**

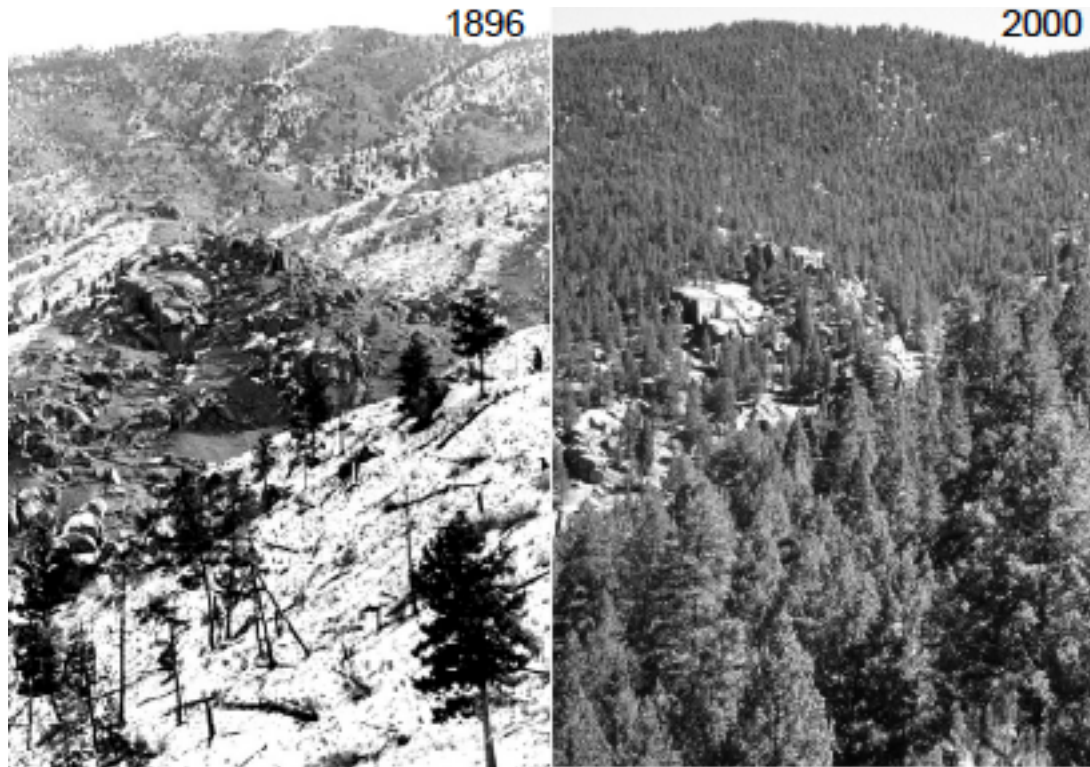
Fire behavior describes the physical characteristics of a fire, primarily its rate of spread (linear distance traveled per unit of time); flame length, height, and depth; and heat energy released over space and time. Research on fire behavior provides managers with information on the way a fire burned, how fires in the general

geographic area under similar conditions might burn in the future, and the effects the fire might have on the vegetation, wildlife, soil, watersheds, and human communities spanning distances greater than the fire itself.

Drawing on the *Hayman Fire Case Study* (Graham 2003), the Hayman Fire behavior was a result of a convergence of regional climatic and weather trends, and local forest conditions. From 2000 through the Spring of 2002, Colorado's Front Range experienced below normal precipitation and acute drought, producing exceptionally low live foliage moisture – the amount of moisture held in the leaves of living plants. The lower the live foliage moisture, the more easily plant material can ignite and burn. The weather prior to the fire was warmer than average, with high southwesterly winds. In the first 48 hours after ignition, the Hayman Fire grew to 60,000 acres due to the high winds and low relative humidity. Fire behavior was extreme, with high rates of spread, long flame lengths and heights, and high heat energy output as evidenced by the large smoke plumes.

In addition to the extreme fire weather, the local forest conditions in the Hayman Fire vicinity were poised to burn with high intensity. Research by Merrill Kaufmann and colleagues at the USDA Forest Service's Rocky Mountain Research Station demonstrate that, due in large part to decades of livestock grazing and suppressing fires, and a lack of any mechanical tree cutting or vegetation removal, the Ponderosa pine forests around the Cheeseman Reservoir area were much more dense and included more Douglas-fir trees than would have been if fire was allowed to play its natural role over the past 100 years. Where the historic forest was likely composed of clumps of primarily Ponderosa pine trees interspersed with grassy

openings, the forest of 2002 had near-continuous, multi-story tree cover composed of Ponderosa pine in the overstory and Douglas-fir in the understory. As a consequence, the forests were highly susceptible to having surface fires spread rapidly from the ground vegetation into tree crowns, and having fires spread rapidly from crown to crown.

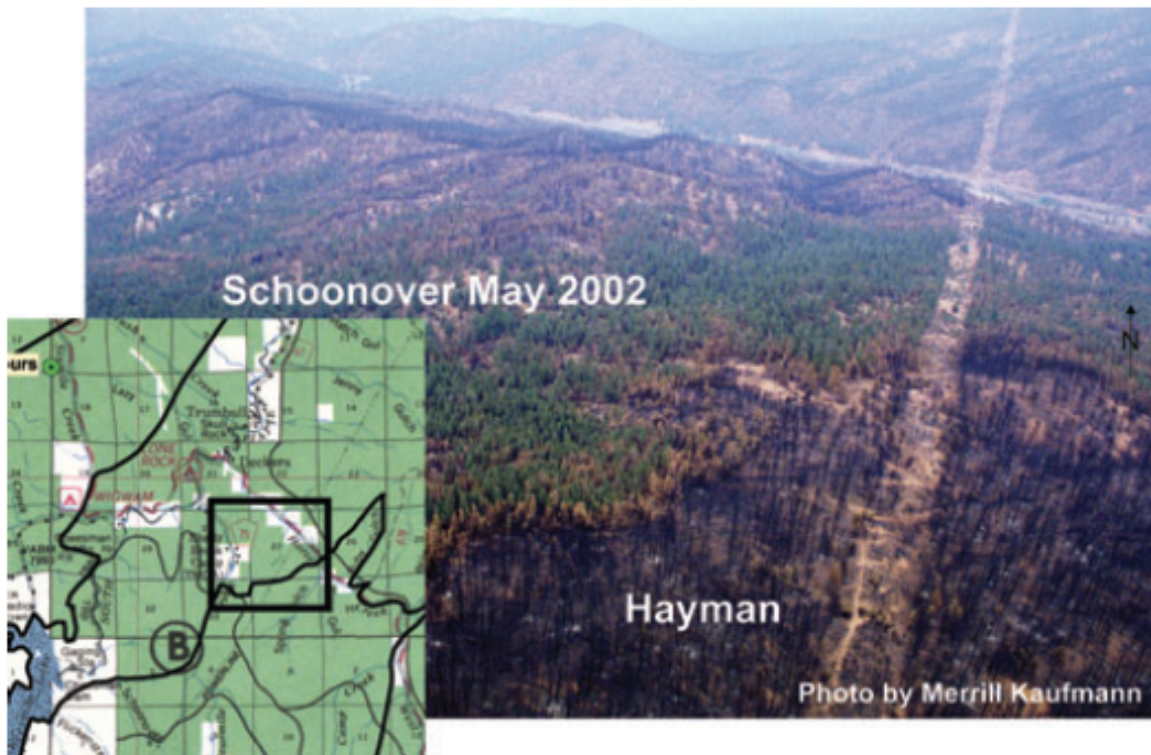


Forest change from 1896 to 2000 near Cheeseman Reservoir (Kaufmann, Veblen, and Romme 2006)

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After the Buffalo Creek fire burned in 1996 and resulted in high sediment loads into Denver Water's Strontia Springs Reservoir, forest managers ramped up efforts to break up continuous forest cover and reduce the chance of extreme fire behavior using mechanical tree thinning and prescribed fire. However, most of the fuel treatments that were within the interior of the Hayman Fire were overwhelmed

by the extreme fire behavior during the first 48 hours following ignition and had little effect on lowering fire intensity. Two previous wildfires, the Big Turkey (May 1998) and the Schoonover (May 2002), and the Polhemus prescribed fire in October 2001 did have demonstrated effects on reducing fire growth and intensity (Martinson, Omi, and Shepperd 2003). These areas had lower amounts of ground fuels (e.g., grasses, forbs, shrubs, needles, branches, and downed trees) and fewer understory trees – two critical factors in causing a fire to spread from the surface to tree crowns. Most of the area burned by the Hayman occurred at the beginning and the end of the fire, with the majority of the acreage burned in the first ten days after ignition (Graham 2003).



Aerial photo showing the effect of the Schoonover wildfire had on the Hayman Fire (Photo from Graham 2003)

In addition to the fire behavior and fuel treatment findings in the *Hayman Fire Case Study* report, Lezberg and colleagues (2008) studied the influence that decades-old fuel treatments had on changing fire behavior of the Hayman Fire. Fortuitously, a study site was established in 1981 to examine the effects of two harvest treatments: a shelterwood cut leaving 50 trees/hectare and a seed tree harvest leaving 12 trees/hectare. The Hayman Fire swept through the site on July 9, 2002 and was documented by the authors as burning with low to moderate severity. Burn severity did not differ among shelterwood and seed tree harvests. Litter and duff quantities were the main factors affecting burn severity. Areas that had litter and duff removed through soil scarification treatments experienced lower burn severity levels; burn severities were higher underneath trees due to higher litter and duff levels (Lezburg, Battaglia, and Shepperd 2008).

Large wildfires can have a significant effect on surrounding weather. There has been documentation of large wildfires influencing the surrounding weather affecting communities far beyond the fire location, including cloud-to-ground (CG) lightning strikes that could ignite fires some distance from the original wildfire. Lang and Rutledge (2006) analyzed CG lightning strikes downwind of the Hayman Fire. The authors did detect an increase of CG lightning strikes in the Denver area; however, within the immediate fire vicinity, they detected only an increase in aerosol optical depth but not CGs (Lang and Rutledge 2006). Results only modestly support the proposition that CG lightning strikes increase from pyro-cumulus clouds associated with the Hayman Fire.

Last but not least, a critical effect of a wildland fire is smoke. The emissions given off by a substantial wildfire may affect public health and safety, regional air quality, and global climate. The Hayman Fire emitted up to five times the carbon monoxide emissions that were created by all Colorado industries in 2002. Most of the fire's emissions and particulates occurred after the 48-hour episode of extreme fire behavior on June 10, 2002 but continued for 13 days (Graham 2003).

## **Wildlife**

Limited published research is available concerning the effect of the Hayman Fire on wildlife. Primarily, research has examined the effects of the Hayman Fire on two bird species, the American three-toed woodpecker (*Picoides dorsalis*) and the flammulated owl (*Otis flammeolus*). Within the Hayman Fire perimeter, American three-toed woodpeckers appear to have selected foraging patches based on burn severity and tree size (Kotliar, Reynolds, and Deutschman 2008). The birds preferred moderate and low burned severity areas instead of high severity areas; lower burn severity is correlated with denser beetle populations – a primary food source for the woodpeckers. Within patches of the same severity, beetle occurrence was better at explaining foraging patterns. Large standing dead trees – snags – resulting from the Hayman Fire were found to be beneficial to woodpeckers and other wildlife species (Kotliar, Reynolds, and Deutschman 2008).



Standing dead trees - or snags - 8 years after the Hayman Fire  
(Photo: Paula Fornwalt)

Also, burn severity may affect mating patterns of flammulated owls. The Hayman Fire appears to have caused a decrease the density of breeding males relative to females; additionally, the first observed instance of polygyny for flammulated owls occurred on a study in 2003 after the Hayman Fire (Linkhart, Evers, and Megler 2008). One male was observed feeding two different females and their brood. The nests were approximately 500 meters apart with each brood consisting of three owlets. During the study, researchers observed two owlet deaths associated with the polygamous brooding males. Documenting mortality among flammulated owls is uncommon and male provisioning was likely reduced in this occurrence of polygyny. The owlets that died were part of a second brood born at a later date, possibly contributing to the mortality (Linkhart, Evers, and Megler 2008).

## Native and Non-Native Understory Plants



Plant growth 8 years after the Hayman Fire (2010) (Photo: Paula Fornwalt)

Fires create opportunities for both native and non-native invasive plants to establish and thrive. Non-native invasive plants in particular, like spotted knapweed (*Centaurea maculosa*) and cheatgrass (*Bromis tectorum*), are recognized as high priority to monitor and prevent disturbance invasion (Graham 2003). Several research papers have been published investigating the dynamics of plant recovery and non-native invasive plant establishment following the Hayman Fire. The composition and richness of post-fire plant establishment is likely related to fire severity.

In sum, studies indicate that the areas experiencing the highest-severity burns during the Hayman Fire saw the highest chances of non-native plant establishment (Fornwalt 2009; Freeman, Stohlgren, and Hunter 2007; Hunter, Omi, and Martinson 2006). Areas that burned with low or mixed-severity tended to have lower chances of non-native plant establishment. Pre-fire fuel treatments (mechanical tree thinning and prescribed fire) and post-fire straw mulch treatments had no statistically-significant effect on changing rates of non-native plant establishment compared to untreated areas; the main factor affecting non-native plant invasion was high-severity burn.

Researchers at the Rocky Mountain Research Station also studied the influence of mixed severity fire on plant species cover and richness (Fornwalt 2009; Fornwalt, Kaufmann, and Stohlgren 2010). Overall richness was unchanged during the first post-fire years compared to pre-fire levels; only short-lived forbs cover varied with fire severity. These results demonstrate the resiliency herbaceous cover can have even after severe fires (Fornwalt, Kaufmann, and Stohlgren 2010). Woody plants however, were slow to recover after the fire and never reached pre-fire levels five years after the fire. Species like mountain mahogany (*Cerocarpus montanus*) and creeping juniper (*Juniperus communis*) may take several years to recover after a wildfire.

Relatedly, Liang (2005) completed a thesis at Colorado State University on the sprouting mechanisms of mountain mahogany and concluded that mahogany will sprout after wildfires and sprouting behavior is correlated to burn severity. Like several plant species associated with Colorado's Front Range Ponderosa pine

ecosystems, mountain mahogany is well adapted for historic mixed fire severity events (Liang 2005).

## **Soil**

Wildfires affect soil properties such as water repellency and soil chemistry. In turn, these can lead to soil erosion and chemical leaching under the right precipitation conditions. With a large portion of the Hayman Fire having burned with high severity, there was and continues to be concern about erosion by land managers and neighboring communities.



Bare soil exposed during the Hayman Fire (Photo: Merrill Kaufmann)

Several papers were published on the Hayman Fire in examining the relationship between burn severity and erosion, and the effectiveness of post-fire

rehabilitation efforts on reducing soil erosion. Concerning water repellency of soils, or hydrophobicity of soils, research concluded that soils with higher than 30% ash content may be considered water repellent soil (Lewis, Robichaud, and Frazier 2008). This information can be mapped remotely using hyperspectral imaging to help determine post-fire water repellent soils to prioritize restoration efforts. Surface soil water repellency generally increased as burn severity increased in the Hayman Fire (Lewis, Robichaud, and Frazier 2008; Lewis, Wu, and Robichaud 2006). Low burn severity plots had weak surface soil water repellency. Moderate and high burn severity plots, however, did not have significantly different surface soil water repellency.

Regarding post-fire rehabilitation, in areas where straw mulch and contour-felled logs were applied, erosion was effectively reduced (Lewis, Robichaud, and Frazier 2008; Lewis, Wu, and Robichaud 2006; Robichaud, Lewis, and Laes 2007). On the other hand, research demonstrated that erosion was not effectively reduced using soil scarification and seeding (Fornwalt 2009; Rough 2007). In Fornwalt's (2009) research, seeding treatments did not produce any viable grass and scarification treatments were ineffective due to a lack of seed germination. The low seed planting depth achieved from the all-terrain vehicle plow-driven scarification treatments and dry summer conditions may have contributed to such poor results. Seeding and scarification seemed to have no effect on native and non-native plant richness or cover. Rough (2007) concluded that dry mulch and aerial mulch were highly effective in reducing erosion. Mulch treatments are effective by preventing rainsplash erosion, preventing moisture evaporation and trapping sediment.



Mulch and seed treatment in the Hayman Fire burn area (Photo: Merrill Kaufmann)

Robichaud (2005) also published a paper evaluating rehabilitation effects on hillslope erosion. Sediment fences were installed in paired catchments to compare post-fire rehabilitation to areas with no treatment. Rehabilitation treatments included contour-felled log erosion barriers, aerial straw mulch, salvage logging and hydromulching. Preliminary analysis concluded that timing, duration, and amount of rainfall are the biggest factors in determining erosion after a fire. The analysis also showed contour log erosion barriers to be highly effective on the Hayman Fire. Other factors include soil type, topography and ground cover. A web-based erosion risk management tool has been developed to help manager decide on which erosion treatment to use (Robichaud 2005).

Lezburg et al.'s (2008) paper on 21 year-old silviculture treatments also looked at nitrogen availability in relation to burn severity and found a trend in nitrogen availability increasing with burn severity. This trend also corresponded to

the amount of litter and duff cover, with the old scarification treatments producing less available nitrogen after the fire. These results are similar to other studies examining the effects of complete removal of the forest floor on soil nitrogen (Lezberg, Battaglia, and Shepperd 2008).

## **Water**

High severity fire events can alter stream chemistry and decrease the density of aquatic invertebrate populations in burned areas (Hall and Lombardozzi 2008). Depending on the severity, effects can last hours to centuries (Rhoades, Entwistle, and Butler 2011). Colorado receives 90% of its water supply from above ground sources; the upper South Platte drainage is recognized as a sensitive watershed due to its reliance for Denver's water supply. Approximately 50-70% of Hayman Fire area was classified as moderate to high severity burn, with 20-95% of individual streams flowing through what was considered moderate to high severity burn (Kershner et al. 2003).

Two separate research projects evaluated the effects the Hayman Fire had on stream water chemistry (Hall and Lombardozzi 2008; Rhoades, Entwistle, and Butler 2011). Results showed a 4-degree increase in temperature in moderate to high severity burned streams. Calcium (CA<sup>+</sup>), Nitrogen (NO<sub>3</sub><sup>-</sup>), and conductivity had also increased in water sampled. Furthermore, turbidity significantly increased in burned streams compared to unburned, but results varied by seasonal conditions (Rhoades, Entwistle, and Butler 2011).



Mass soil loss and watershed effects from the Hayman Fire  
(Photo: Denver Water)

Aquatic invertebrates were also affected in the upper South Platte water systems from the Hayman Fire (Hall and Lombardozzi 2008). Compared to reference streams, there were significantly fewer individuals and lower biomass in three invertebrate orders (Diptera, Coleoptera, and Trichoptera). Invertebrate density sampled in burned area streams was 60% to 80% less for all invertebrates during the first two years after the Hayman Fire. Significantly fewer taxa were present in the first year after the fire with diversity rebounding by the second year sampled. Results also showed an increase in nitrogen content in coleopteran invertebrate order, with nitrogen body concentrations increasing from 9.7% to 11.2% (Hall and Lombardozzi 2008).

Denver and surrounding areas had potentially high risks after the Hayman Fire. Even though nitrogen and turbidity levels rose significantly, water quality still exceeded federal drinking water standards in a positive direction

(Rhoades, Entwistle, and Butler 2011). Aquatic invertebrates are also affected by high nitrogen concentrations, high turbidity, and low diffuse oxygen levels caused by the high burn severity parts of the Hayman (Hall and Lombardozzi 2008). Water quality may need further investigation on a larger scale, far beyond the direct effects of a wildfire. Prescribed fire, forest thinning, and erosion control treatments may prevent the detrimental effects of high burn severity fire events such as the Hayman.

## **Social-Economic Issues**

Large, high-impact fires such as the Hayman have complex socio-economic consequences. Unlike many of the ecological effects from a wildfire, socio-economic effects may extend substantially beyond the geographic area actually burned. The Hayman was not an abnormally expensive fire in terms of cost per acre in terms of suppression, but ongoing costs are considerably large. A case study by the Western Forestry Leadership Coalition estimated the ‘true’ cost of the Hayman Fire as approaching \$207 million.<sup>2</sup> As a result, the Hayman Fire is regarded as the most expensive fires in Colorado history. Six-hundred structures were destroyed, including 132 residence, totaling \$24 million in real-estate property losses. Suppression expenditures totaled more than \$42 million. Resource value such as tourism is much more difficult to measure considering the area was closed during the busiest time of the year.

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<sup>2</sup> [http://www.wflcenter.org/news\\_pdf/324\\_pdf.pdf](http://www.wflcenter.org/news_pdf/324_pdf.pdf)

In the *Hayman Fire Case Study* (Graham 2003), a case study was presented on the Ridgewood Homeowners Association (RHOA) adjacent to the eastern edge of the fire. RHOA members commented on having notable experience with wildfire and understanding the potential dangers. They most preferred the use of mechanical treatments in their community, followed by a combination of prescribed fire and mechanical removal. However, RHOA members were somewhat neutral on solely using prescribed fire.

The residents of RHOA feel that there is a high probability that a wildfire will burn in their community in the near future. They understand the risks and the measures needed to mitigate the risks. However little mitigation has been done on homeowners lands. The residents acknowledge the responsibility for defending their property but feel that all neighbors need to be involved in mitigating these risks.



A house that survived the Fourmile Canyon fire in 2010 (Photo: Tony Cheng)

A similar study conducted in the Fourmile Canyon area in Boulder County showed similar results as the RHOA case study in terms of residents' understanding of wildfire risk (Brenkert-Smith and Champ 2011). The Fourmile Canyon fire, though much smaller in size to the Hayman Fire (6,200 acres for the Fourmile Canyon fire compared to 138,000 acres for the Hayman Fire), burned with moderate- to high-severity and resulted in substantial property destruction; about \$218 million in insurance claims made the Fourmile Canyon the most costly fire in Colorado history. Research on residents in the Fourmile Canyon vicinity demonstrates that residents understand the risks of living in a fire-prone landscape. Additionally, even though a vast majority of survey respondents indicated that they performed wildfire risk mitigation actions, such as defensible space and fire-resistant home construction, residents readily acknowledge that fire is an inevitable part of their surrounding landscape.

In sum, many residents in fire-prone landscapes of Colorado's Front Range understand the risks of wildland fire. A large proportion of residents perform mitigation measures; however, challenges remain to coordinate risk mitigation actions across landownerships and jurisdictions to reduce the risk of catastrophic wildfires at a landscape-scale. There appears to be room to better integrate landscape-scale hazardous fuel reduction and forest restoration on federal lands efforts with local, community-based wildfire risk mitigation on non-federal lands.

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