Seventh Oregon Climate Assessment

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Reimagining the Wildfire Challenge and Local Solutions

Ralph Bloemers

As the climate of the western United States becomes warmer and drier, both the area burned and the number of homes lost to wildfires are increasing. The greatest losses occur when dry winds spread fire and burning embers into communities and ignite combustible materials, vegetation, and structures. Burning structures then ignite other nearby structures, causing conflagrations in which hundreds of homes burn in several hours. These urban fires are occurring more often, and in places not previously identified as high risk.

The most destructive wildfires are best understood as "wind events with fire in them" (Donato and Halofsky 2019, Balch et al. 2024). These fires can grow by hundreds of acres per hour, and thousands to tens of thousands of acres per day, overwhelming suppression efforts. For example, the 2018 Camp Fire burned over 18,000 structures in and around the town of Paradise, California, and took 85 lives. The 2020 Labor Day fires in Oregon burned over 1 million acres (4,050 km^2) and destroyed communities believed to be at low risk for wildfire. In 2021, the Dixie Fire became California's largest on record (Branson-Potts 2021), and the Marshall Fire, while small, grew rapidly and destroyed more structures than any other fire on record in Colorado (Branson-Potts 2021, Holmstrom et al. 2022). In July 2024, the Park Fire outside Chico, California, grew to over 400,000 acres (1,618 km^2) at a rate of about 4,000 acres (16 km^2) per hour.

Between the decades of 1999–2009 and 2010–2020, the number of structures lost to wildfires in the western United States increased by 246 percent (Higuera et. al. 2023). For several decades, wildfire prevention efforts in the United States have focused on vegetation clearing and other forms of land management (USFS 2023). Yet during periods of extreme fire behavior with high winds, thinned forest plantations, areas treated with prescribed burns, fuel breaks, dirt roads, city streets, multiple-lane highways, and natural barriers such as the crest of the Sierra Nevada did not prevent fire from spotting over great distances or igniting fuels (Syphard 2011, Boxall 2019, Siegler 2021).

Destructive fires ignite and spread in all vegetation types. For example, two ignitions leading to the burning of dry grasses and shrubs in Boulder County, Colorado, generated enough embers to ignite and then burn 1,057 homes in the Marshall Fire in six hours. In August 2023, wind drove fire into Lahaina, Hawaii, and caused structure-to-structure ignitions, leaving at least 102 people dead and two missing. Over 70 percent of the more than 1.8 million acres burned in Oregon in 2024 as of 28 October, when the Oregon Department of Forestry ended fire restrictions, were grasslands and shrublands (Wildland Mapping Institute 2024).

More than four years after the 2020 Labor Day fires, many of the Oregonians who survived these fires, but lost their homes, are still struggling, and most of the communities are only partially rebuilt. A number of survivors died before receiving compensation for their economic and emotional losses. These survivors and all Oregonians need a clear-eyed understanding of the threat that wildfire poses to communities and scalable ways to prevent homes from burning.

I have worked on forest and wildfire issues in the Pacific Northwest for over 20 years. I have spent time with firefighters, fire scientists, and fire survivors. For over seven years, I have taken extensive time-lapse and wildlife photographs in burned landscapes (Figure 1), and worked with journalists to report on fires across the West. My focus is on stories that distill the best science, identify the dominant factors that lead to home and community losses, and motivate people to take actions to protect life and property and make their homes savable in the most extreme conditions. From 2017 to 2022, I worked with a team to produce *Elemental: Reimagine Wildfire*. I then traveled across the United States and Canada to screen the film in hundreds of theaters and at community events, conferences, K-12 schools, and universities. Time and again, I found that people are eager for solutions that are based on a proper problem definition and actions they can take on their own home and property.

Figure 1. Black bear (*Ursus americanus*) in 2022 within an area that burned at high severity during the 2017 Eagle Creek Fire, Columbia River Gorge, Oregon. Photograph by Ralph Bloemers.

Ample research demonstrates how to prevent losses of life and property via actions that largely are adjacent to homes, and durable. The question is whether society can shift from investing in fire suppression and vegetation management that defines the inevitable wildfire as the problem and instead mitigate the risk of home ignition, even in the most extreme fire weather (Calkin et al. 2023). Making this shift requires reimagining humans' relationship with fire, which in turn necessitates acceptance of the natural reality of fire and preparation of homes and communities well before fires ignite.

Dominant Cultural Narratives About Wildfire

In the twenty-first century, technology and media influence many aspects of people's thoughts, perceptions, and social constructs, and have affected the way that society in the United States views natural events. Wildfire is an emotional topic, and news coverage is filled with stories about devastating losses of lives, homes, and other property. Stories about fires in natural areas such as Yellowstone and Yosemite National Parks, the Columbia River Gorge, and the Cascade Range have often represented fires as catastrophes instead of as natural processes that renew, restore, and maintain ecosystems.

In his book *Media and Apocalypse*, Conrad Smith (1992) examined the media coverage of the Yellowstone fires of 1988. Conrad Smith loved Yellowstone, and was distraught when he learned from news reports that it had burned. Then he visited the burned area in 1990 and discovered that the regrowth in burned areas was prolific. He interviewed hundreds of people, and identified three dominant perceptions about fire: fire destroys forests and other vegetation, fire kills all wildlife, and people can and should be in control of fire. The narrative that fire is big, bad, and must be put out is powerful and widespread. These beliefs reinforce the message that wildfire is the problem and that the problem is solved by management of forests: that people can reduce smoke, protect communities, or limit the expense of wildfire suppression by reducing the volume of vegetation or altering the canopy in forests, and then maintaining the reduction of vegetation over time and space.

Forests and other ecosystems burn, and then regrow (Figure 2). Homes that burn, of course, do not regrow. Yet this significant distinction sometimes is blurred by the media, and an urban view of fire is superimposed on wildlands. Wildfires are often depicted in terms of disaster, damages, and victims, with stories that center on how, where, and what they burn. A forest is "destroyed" or "nuked" by "catastrophic" "megafire" (Stoof et al. 2024). Although there are high-quality aspects of wildfire coverage, reporting on wildfires routinely personifies harm, emphasizes the graphic effects of the events, and relies on generalizations about cause and effect that are inconsistent with scientific understanding (Fire Learning Network 2024). This rhetoric affects the public's conception of wildfires. Media outlets and government officials are challenged in portraying events accurately, with context, nuance, and paradox, rather than presenting a stereotype of a disaster. They are also hampered by the fact that hyperbolic headlines often boost readership and views. Limited reporting on the social, political, and scientific contexts of wildfires creates a disconnect between public perception of wildfires, an understanding of the reality of and reasons for their occurrence, and viable, scalable ways to reduce losses.

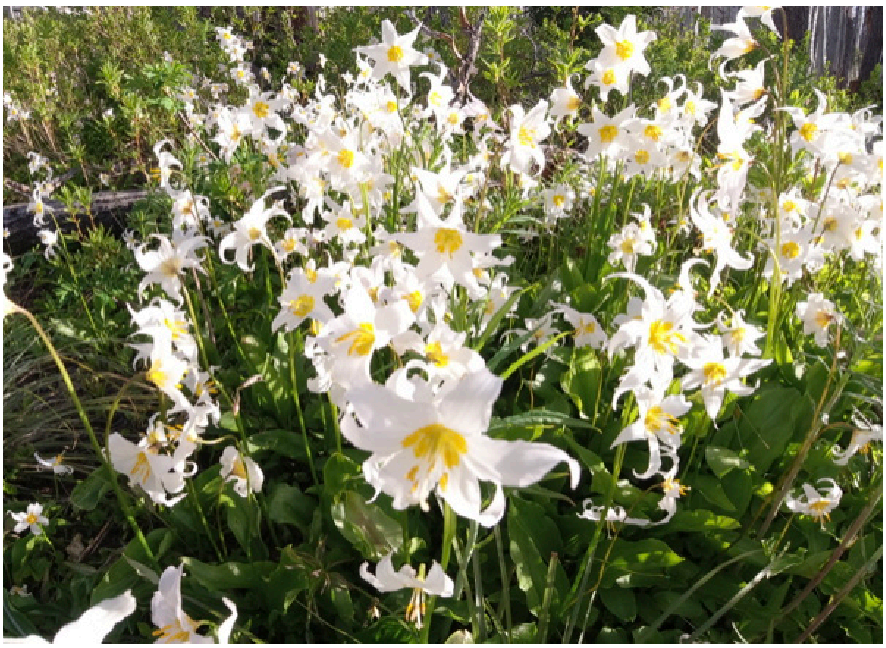

Figure 2. Avalanche lilies (*Erythronium montanum*) in an area recovering from the 2011 Dollar Lake Fire, Mt. Hood, Oregon. Photograph by Ralph Bloemers.

Coverage of fire in forests is full of references to acres consumed or destroyed without an examination of what is happening within the fire perimeters (Ingalsbee 2007). The entirety of Yellowstone National Park did not burn in 1988, although some Americans concluded it had after reading press accounts of the fires or watching the nightly news (Smith 1992). Similarly, the Columbia River Gorge was not destroyed by the Eagle Creek Fire. Although the fire perimeter enclosed around 50,000 acres (202 km^2), only 8,000 acres (32 km^2) burned at high severity (killed most of the vegetation). The remainder of the area burned at low or moderate severity or was unburned (USFS 2017). Eight years later, the high severity patches are full of new growth, and wildlife is abundant. Fires do not ordinarily destroy forests or cause animals to flee in terror, as suggested by some media networks and Walt Disney Productions' movie *Bambi*.

Public Perceptions of Wildfire Control and Responsibility

The most immediate, major concern when a wildfire ignites is protecting human life and property. When communities burn, blame often is placed on officials and agencies who attempted but failed to suppress wildfire regardless of whether suppression is realistic. For decades, the dominant belief that wildfires can be controlled or stopped has led society to prepare for fire ineffectively.

Media coverage of wildfires generally is similar to that of other disasters in that it highlights the damages and the vivid impacts. The public's preconception that wildfire can be controlled determines how stories about fires and their causes and solutions are reported and received. Earthquakes and hurricanes are considered to be uncontrollable, whereas fires are considered to be controllable, leading to unrealistic public expectations during extreme fire weather conditions. Most fires are controllable, but extreme fire behavior is not. When societal expectations of control are not met, the public's perception of institutional ineptitude is reinforced.

Stories to Protect Oregonians

In 2017, in the wake of the Eagle Creek Fire, I worked with Trip Jennings, a filmmaker based in Oregon, to document the extent of the burn. We produced numerous short films about ecological recovery in the Columbia River Gorge. For example, we flew over the burned area with John Bailey, a professor at Oregon State University, and *Oregonian* reporter Kale Williams. Lisa Ellsworth, an Oregon State University scientist, took us to forests in the Clackamas River drainage that had burned in a fire several years before and explained how quickly the forest grows back after fire. *The Oregonian* picked up the film, communities throughout the Columbia River Gorge played it at forums, and media outlets shared our photographs to help Oregonians make sense of the fire.

Over the last seven years, Trip and I deployed time-lapse and wildlife cameras in areas that burned at high severity throughout the Columbia River Gorge; in the Clackamas, Santiam, and McKenzie river corridors following more recent fires; and in areas in the Klamath-Siskiyou Mountains and on Mt. Hood that burned in the past. With these cameras, we documented the return of life to burned areas, and our images have been featured in the Oregon Public Broadcasting Field Guide (Profita 2021), KOIN (Arden 2023), KGW News (2024), *The Statesman Journal*, *The Register Guard*, and numerous films.

With support from National Geographic, Film Action Oregon, the Oregon Community Foundation, Meyer Memorial Trust, and the Lazar Foundation, I worked with Trip's team at Balance Media Productions to produce *Elemental: Reimagine Wildfire*. I shot photographs, examined fire science, interviewed scientists, secured the film's narrator, and worked with a fact-checking team to produce the film. The film helps viewers understand the dominant factors in structure loss in extreme fires, the benefits of fire in forests in the western United States, and actions to prevent the losses of homes. After two years on tour and hundreds of theatrical screenings, special events, and professional conferences, most with a public question-and-answer session afterward, I have seen how stories can help people live with fire and adapt to more extreme weather in a changing climate. The following are ten major insights from the fire survivors, fire and home safety researchers, meteorologists, Indigenous fire lighters, and firefighters who are featured in the film.

Firefighting has Limits

The opening scenes of *Elemental: Reimagine Wildfire* are narrated by a young couple, a nurse, and a firefighter who survived the Camp Fire. Survivors' stories help people understand the conditions that lead to the greatest losses: a wind-driven ember storm entering a community that ignites homes, which in turn become the fuel that ignites other homes (Cohen 2000, Joyce 2018).

After-action reports on destructive fires reveal that these fires were not controlled until the weather conditions changed. Although investments in wildfire suppression and vegetation management have significantly increased, the number of homes lost to wildfires has increased exponentially. Urban conflagrations in Santa Rosa, Malibu, Ventura, and Paradise, California; Superior, Colorado; Talent and Phoenix, Oregon; and Lahaina, Hawaii; have exceeded the limits of firefighting capacity. A small number of fires cause most of the life and property loss (Balch et al. 2024). These are wind-driven fires that escape suppression and either skip over or burn through vegetation treatments. Stemming the losses from these fires require people to focus on preparing homes to resist ignition instead of expecting that a fire can be controlled.

During the film's production and on our nationwide tour, firefighters shared how important it is for the public to understand the limits of firefighting and shift perceptions away from the dominant narratives of heroes in a firefight and megafires (usually defined as fires larger than 100,000 acres [405 km^2]) that can and must be suppressed at all costs. To bring the limits into sharp focus, firefighters who responded to the Camp Fire explained that five or six fire engines are needed to defend a single structure in a wind-driven fire, and many more are needed to douse the fire if the structure ignites. To put this in perspective, for firefighters to have had a chance of saving one-third of the more than 18,000 structures that were lost in the Camp Fire, every fire truck in California would have needed to arrive in Paradise in less than an hour. During wind-driven fires, aircraft may be grounded, and even if they can fly, the water or retardant they drop barely reaches the ground. Sharing the limits of fire suppression informs reasonable public expectations, and in turn motivates action before fires ignite.

Most Destructive Fires Are Wind-Driven and in Grasslands and Shrublands

Considerable attention and resources are directed at fire in forests, yet fires burn in grasslands and shrublands, too. From 1990–2020, wildfires in grasslands and shrublands burned 80 percent of the homes and structures lost to wildfire in the conterminous United States (Radeloff et al. 2023). The vegetation types that tend to burn in fast fires, defined as fires that grow by over 4,000 acres (1619 hectares) per hour, are mostly grasses and shrubs. Fast fires led to 88 percent of the home and structure losses across the conterminous United States from 2001–2020 (Balch et al. 2024).

Sixty percent of homes lost to wildfires in the western United States from 1999–2020 occurred during wildfires driven by downslope winds (Abatzoglou et al. 2023). All types of vegetation can produce embers that ignite receptive fuels in and around homes. For example, embers can ignite bark mulch next to the structure, fine plant material in gutters, and fences against which the embers accumulate (Joyce 2018). The burning bark mulch, fine plant materials, or fences become the pathways to home ignition. The greatest risk is not from a wall of flames in the tree canopy bearing down on a community. Experiments and after-action reports from numerous fires demonstrate that the intensity of a wildfire is not directly related to ignition of homes and other structures (Cohen 1999, 2000, 2004; Cohen and Westhaver 2022).

Wildfires ignited by human causes accounted for 76 percent of structure losses in the western United States from 1999–2009 (Higuera et al. 2023). Over that period, the median number of structures lost per unit area burned by human-ignited fires was ten times greater than that burned by lightning-ignited fires (Higuera et al. 2023). Across the conterminous United States from 1992–2012, human-caused wildfires accounted for 84 percent of all wildfires and accounted for nearly half of the cumulative area burned (Balch et al. 2017). Human-caused ignitions have tripled the length of the fire season, extending it into months when lightning is rare (Balch et al. 2017, Coop et al. 2022).

Weather and Climate Drive Large Fires

Among the factors contributing to increases in the area burned and the duration of the fire season across the western United States are decreases in vegetation and soil moisture as a result of higher temperatures. The resulting drier vegetation enables rapid fire growth, particularly when it coincides with strong winds (Abatzgolou and Williams 2016, Abatzgolou et al. 2023). Ecosystem modifications, including expansion of non-native invasive grasses and conversion of native forests to tree plantations, also contribute to fire risk. The frequency of extreme fire weather is increasing, nights are becoming more conducive to burning, and fires are burning at higher elevations (Bowman et al. 2020, Alizadeh et al. 2021, Balch et al. 2022). For example, limited late summer, autumn, and early winter precipitation in Colorado's Front Range left grasses dry and flammable, which facilitated the spread of the wind-driven Marshall Fire. Reduction in wind speeds and heavy snow on the following day led to containment (Colorado Division of Fire Prevention and Control 2021).

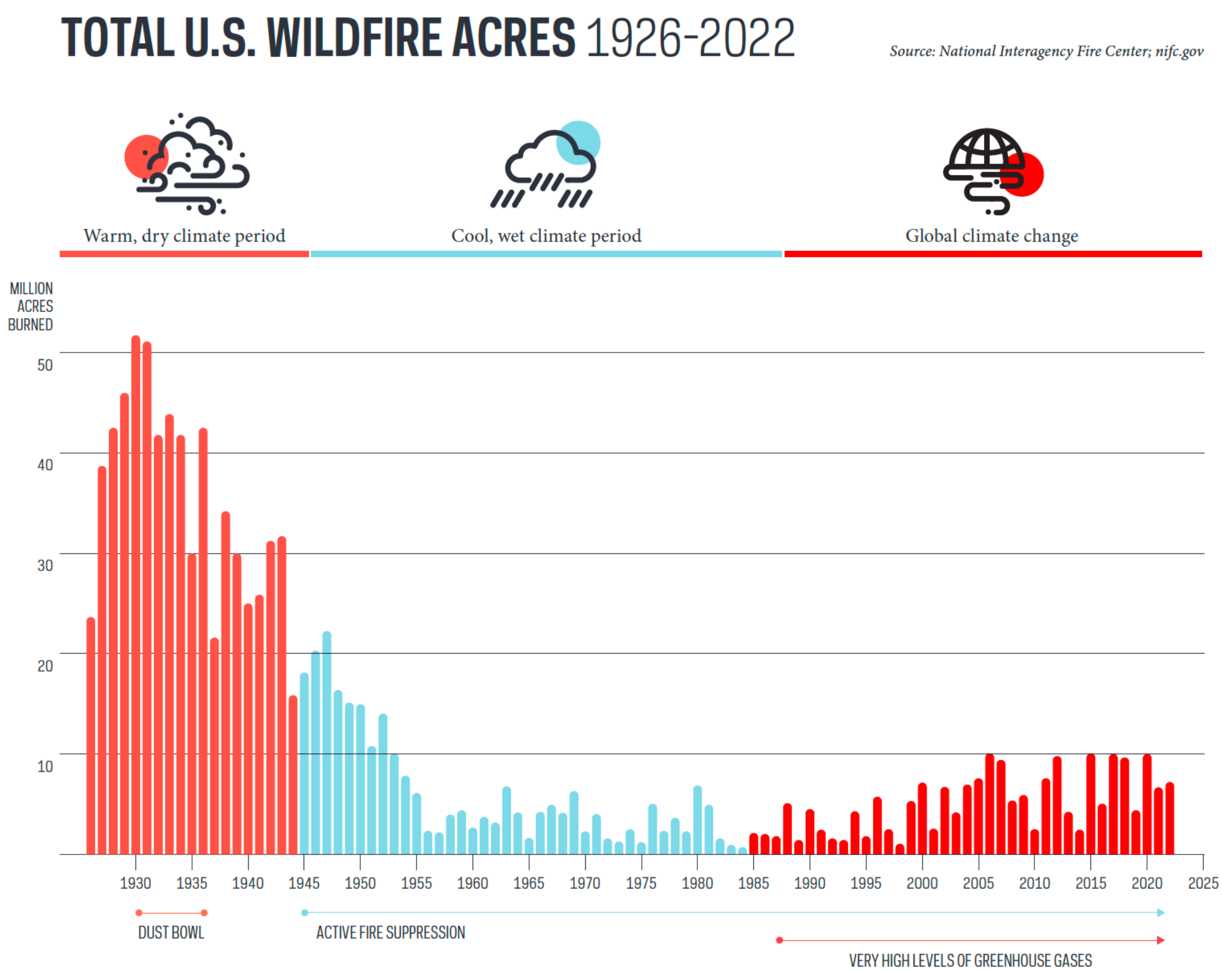

Figure 3. Variability in climate, trends in land management, and human-driven climate change contribute to variability in area burned in the conterminous United States.

Human-induced climate change contributed to a doubling of the area burned in western forests from 1984 through 2015 (Abatzgolou and Williams 2016). Large fires, such as the Lionshead (Oregon, 2020), Camp (California, 2018), Woolsey (California, 2018), Glass (California, 2020), and North Complex (California, 2020), often co-occur with low fuel moisture, high downslope winds, and high temperatures (Abatzgolou et al. 2023). Although the annual area burned in Oregon and the western United States since the 1980s has increased considerably, creating the impression that the extent of fire is unprecedented, the area burned is similar to that during earlier decades with relatively warm and dry conditions (Figure 3). (Littell et al. 2009, ODF 2022). Aridity of the atmosphere and vegetation were significant contributors to the annual average area burned in the western United States in the last decades of the twentieth century and first two decades of the twenty-first century (Abatzgolou and Williams 2016, Coop et al. 2022).

As climate change increases the odds of large fires and extreme fire behavior in the western United States, fire suppression is becoming less viable as a way to mitigate wildfire risk than it was from the 1940s through the 1980s. Although fire size attracts considerable attention, speed has a stronger effect on the potential for destruction of homes and communities. Downslope wind events, such as the easterly winds that are common in late summer and autumn in Oregon, are associated with significant losses (Abatzgolou et al. 2021, Evers et al. 2022).

Focus Investments From the Home Outward

As home losses increase, numerous insurance providers are not writing new homeowners policies in any or large parts of the California market because the financial risk is too high. Insurance retreat, which also is occurring in Oregon (Baumhardt 2024), is prompting a reexamination of which strategies for preventing home loss are most effective. For several decades, the U.S. Forest Service's Missoula Fire Sciences Laboratory, National Fire Protection Association, Insurance Institute for Business and Home Safety, Underwriters Laboratory's Fire Safety Research Institute, and National Institute for Standards & Technology have studied causes of home losses and how the losses can be prevented. Their experiments and analyses consistently suggest that the design and maintenance of a home and the five feet around it, or the home ignition zone, are critical for reducing the chance that the home will ignite (Figure 4) (Cohen 2004, Cohen and Westhaver 2022, Hedayati et al. 2023, Kerber and Alkonis 2024). Although structures can ignite from intense radiant heat within 30 ft. (9 m), the most effective actions are close to the structure. In contrast, attempts to control fire intensity by altering vegetation over large areas have a limited probability of success (Schoenagel et al. 2017).

The Wildfire Prepared Home, a new certification by the Insurance Institute for Business and Home Safety, focuses on that home ignition zone. The distance between many homes and the property boundary is no more than 5 ft. (1.5 m), and the distance between neighboring homes is often not more than 10 ft. (3 m). Therefore, recommendations to address defensible space beyond those distances—often 30, 60, or 100 ft. (9, 18, or 30 m) from the home—can be confusing and discourage action. The top five recommendations provided to homeowners in over 100,000 fire preparedness assessments conducted in 2023 and 2024 with the Fire Aside application focus on actions in the immediate area around the home (Figure 5) (Fire Aside 2024).

Showing people videos of home-ignition experiments (Figure 4) and homes that have survived extreme fire illustrates the dominant influences on home loss and underscores that they have the power to prepare their homes for fire. Insurance companies are also telling homeowners that these preparations are needed to make the companies' risk acceptable and stabilize insurance markets (PBS 2023). Although a full retrofit may cost $100,000, the cost of retrofits such as installing ember-resistant vents or metal flashing along a deck, or replacing combustible mulch next to the house with pavers or stone, is $2,000–15,000 (Barrett and Quarles 2024). The cost of building new homes that are resistant to wildfires is equal to that of traditional construction (Quarles and Pohl 2018).

Figure 4. Testing resistance of home building and landscaping materials to ignition from wind-blown embers. Photograph courtesy of ElementalFilm.com.

Effects of Vegetation Management on Fire Behavior are Uncertain

Many contemporary forests in the western United States are fragmented, and in the Pacific Northwest, numerous older forests have been cut and replaced with younger plantations. Forests cover about 30 million acres (121,400 km^2) in Oregon, and nearly 19 million acres (76,890 km^2) are publicly owned. The remainder of Oregon's landscapes are dominated by grasslands and shrublands. Of the 11 million acres (44,510 km^2) of privately owned forest, around 6.8 million acres (27,520 km^2) are managed as tree plantations. Tree removal has the greatest effect on fire behavior if the managed area burns before forest regenerates.

Heavily managed tree plantations that are logged on short rotations tend to burn faster and at higher severity than naturally regenerated forests (Zald and Dunn 2018, Levine et. al. 2022). In a subset of fires that burned in California from 1985 through 2019, the incidence of high-severity fire was greater in areas closer to private industrial land than in areas further away (Levine et al. 2022). Nearly 70 percent of the area burned within the 2020 Holiday Farm Fire in Oregon was in timber plantations (Gavin 2020) (Figure 6). Many of the forests in the western United States have been cut over and replanted, and therefore their structure and the species present are not the same as those during the sixteenth through eighteenth centuries.

The Pacific Northwest's mesic, cool forests, which include about 60 percent of the forests in Oregon, historically burned infrequently. Wildfire dynamics in these systems are characterized as climate-limited rather than fuel-limited. Large fires have occurred in forests west of Oregon's Cascade Range since at least the year 1500 (Spies et al. 2018, Donato and Halofsky 2019). The 2017 Eagle Creek Fire and several of the 2020 Labor Day fires are emblematic of the fires that occur in this region. These events are driven by downslope winds that, when combined with an ignition, result in large fires with rapid rates of spread. Suppression is often not feasible during wind events, and tree thinning with the aim of changing fire behavior is largely ineffective and cost prohibitive in systems in which trees regenerate rapidly and fires tend to be wind-driven (Evers et al. 2022, Reilly et al. 2022).

While thinning and reintroducing fire in a small patch of forest can serve human values, such as reducing risk to infrastructure, the area thinned across extensive public forests has little relation to area burned (Schoennagel et al. 2017). Across the western United States from 2005–2014, roughly one percent of U.S. Forest Service fuels treatments burned each year (Schoennagel et al. 2017). Dry forest types that may be candidates for intervention cover less than one-third of forested area nationwide (Schmidt et al. 2002), and about 40 percent of forests in Oregon (Spies et al. 2018). Furthermore, in ponderosa pine (*Pinus ponderosa*) forests, thinning, prescribed burning, and other maintenance generally must be repeated every 10 to 20 years to be effective (Wasserman et al. 2022).

Statements to the effect that dry forests are unnaturally dense or have burned infrequently and therefore are likely to burn severely evince a focus on low-intensity surface fire. However, efforts to influence outcomes in dry forests are complicated by many factors. For example, mixed intensity and stand-replacing fires (crown fires) historically were common in most dry forests in the western United States (Schmidt et al. 2002), and it is challenging to thin vast areas of trees to reduce the likelihood of these fires over space and time (Rhodes and Baker 2014, Schoenagel et al. 2017). Among 60,000 fires that burned in the conterminous United States from 2001 through 2000, the ten with the fastest single-day growth rates occurred in areas with more than 50 percent grass cover (Balch et al. 2024). Grasses tend to dry quickly, and grasslands provide little friction to slow wind speeds (Balch et al. 2024). To manage wildland fire as a natural disturbance, society needs to accept that fires across a gradient of size and intensity are inevitable, essential ecological processes.

Reduce the Incidence of Human-Caused Ignitions

Since humans discovered fire, deliberate and inadvertent human-caused ignitions have expanded the season during which ignitions occur and the number of ignitions. The U.S. Forest Service's Fire Program Analysis Fire-Occurrence Database, which currently includes more than 2 million wildfires that occurred in the United States

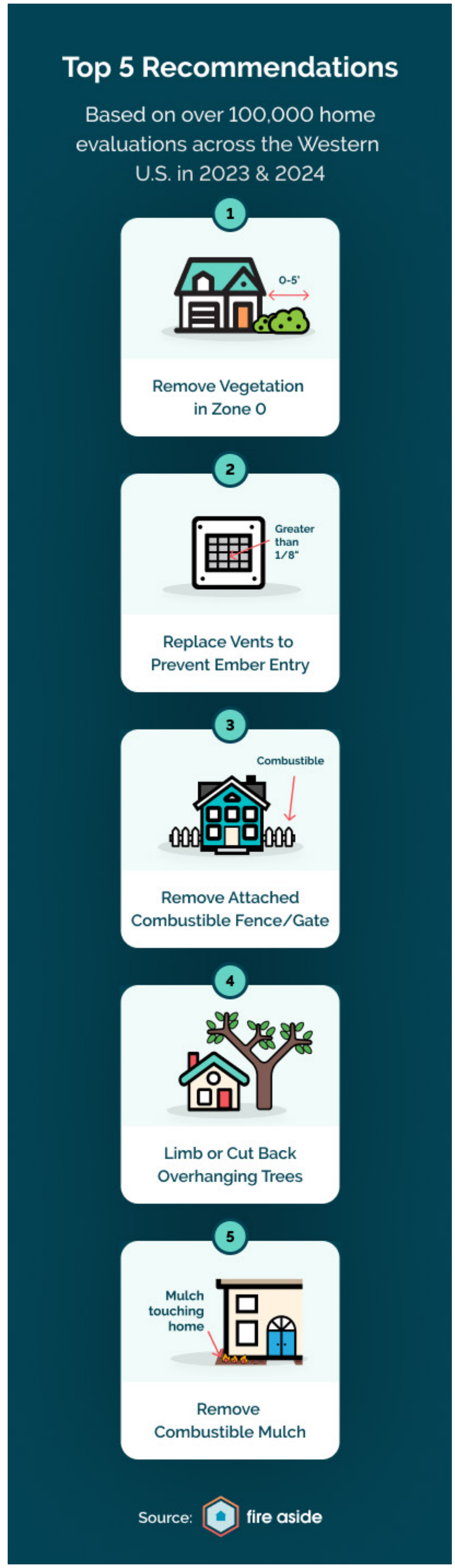

Figure 5. Fire Aside's top five recommendations for reducing the risk of home ignition.

from 1992 through 2020, recognizes 13 ignition causes. The ten classes of human-caused ignitions range from debris and open burning to fireworks to misuse of fire by a minor. Across the western United States, debris and open burning accounted for the greatest percentage of wildfires during downslope wind events (about 30 percent). During periods of downslope winds, wildfires attributed to recreation and ceremony became 116 percent more likely (Abatzoglou et al. 2023). Likewise, those attributed to power generation, transmission, or distribution were 75 percent more likely during downslope winds. From 1992–2015, 97 percent of wildfires ignited in the wildland-urban interface across the conterminous United States were human-caused (Mietkiwiecz et al. 2020). Across the United States, the number of ignitions caused by fireworks spikes on and around 4 July (Mietkiewicz et al. 2020, Vachula et al. 2023). In Oregon, cities increasingly are banning fireworks (De Dios 2024), while federal jurisdictions such as the U.S. Forest Service and National Park Service commonly ban camp fires and other open fires during hot, dry, or windy conditions (e.g., NPS 2024, USFS 2024).

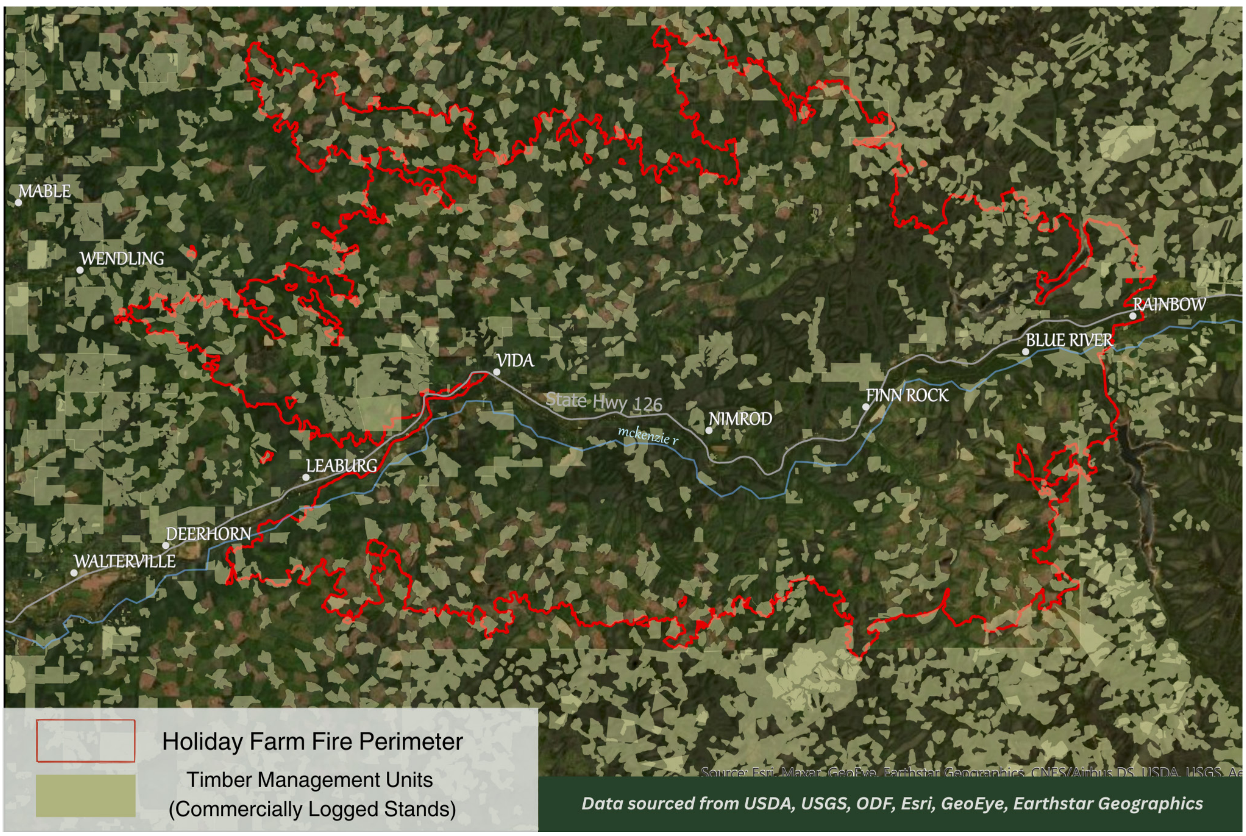

Figure 6. Almost 70 percent of the area within the perimeter of the Holiday Farm Fire, Oregon (8 September–3 October 2020) was in timber plantations. Figure courtesy of Firefighters United for Safety, Ethics, and Ecology.

The Fire Program Analysis Fire-Occurrence Database indicates that debris and open burning caused the greatest percentage of human-ignited wildfires in Oregon from 1992–2020 (14 percent), and equipment and vehicle use led to greatest percentage of area burned (5 percent). Ignitions caused by power generation, transmission, or distribution accounted for two percent of the total number of fires >1 acre, and 0.3 percent of the area burned. Nevertheless, the role of power systems is attracting increasing attention given that they ignited or contributed to ignition of some of the recent wildfires that caused the greatest losses of life and structures. These include the Tubbs (2017, Santa Rosa, California), Camp (2018, Paradise, California), Almeda (2020, Talent and Phoenix, Oregon), Marshall (2021, Boulder County, Colorado), and Lahaina (2023, Maui, Hawaii) fires. From

2015 through 2020, energized power lines ignited six of 20 of California's most destructive fires (California State Auditor 2021). Wildfires ignited by power systems rapidly can become large because they generally begin during periods of high wind.

Public safety power shutoffs increasingly are being implemented with the aim of preventing ignitions from power generation, transmission, or distribution. Use of such shutoffs was approved in California in 2012, and Portland General Electric implemented one in Oregon in 2020. Although shutoffs widely are believed to be effective, few data are available given how recently they were adopted. Utilities in Oregon are encouraging individuals whose medical care requires power to contact their utility provider to ensure that their health is not compromised during a shutoff. Vegetation management along power line corridors, modifications to equipment, and monitoring technologies also are strategies for reducing the number of ignitions from electricity infrastructure.

Most Forest Fires Release Relatively Small Amounts of Carbon

Forest carbon is in a constant state of flux. Vegetation regrows and sequesters carbon after fires, and carbon emissions from forests and other ecosystems often occur in pulses. *Elemental: Reimagine Wildfire* explores the impacts of wildfires on carbon stocks in forests, and viewers are often surprised. Although moderate to high intensity fire can kill trees, most of the carbon remains in the ecosystem as dead wood that decomposes over decades to centuries. From 2009–2018, carbon emissions from timber harvest and burning of fossil fuels in the western United States were 16 times greater than emissions from forest fires (Bartowitz et al. 2022), albeit state-level or regional carbon emissions from wildfires can be considerable in years in which the area burned is high. Emissions of carbon per unit area were 1.5 to 8 times greater in harvested areas than in burned areas because harvest killed a greater proportion of trees (Bartowitz et al. 2022). In part because 1–20 percent of areas in which fuels were reduced are likely to burn within 10–25 years after treatment, it may be necessary to treat an average of 25 acres (10 hectares) of forest to appreciably reduce wildfire potential in a given 2.5 acres (1 hectare) (Campbell et al. 2012). Field-based studies of combustion rates in two large fires in California found that carbon emissions across the entire area burned were equivalent to 0.6 to 1.8 percent of the vegetative biomass (Harmon et al. 2022). In mixed conifer and ponderosa pine forests that burned in fires in 2013 and 2020 in the central and southern Sierra Nevada, California, the majority of biomass was large trees with low combustion rates, and less than half of the area within the fire perimeter burned at high intensity (Harmon et al. 2022). These findings are consistent with field studies from the 500,000-acre (2023 km^2) Biscuit Fire that burned in southern Oregon in 2002 (Campbell et al. 2007).

Oregon's rainforests are among the most carbon-rich forests in the world. When trees are harvested, some of the carbon they stored is released into the atmosphere (Law et al. 2022). Although carbon estimates depend on available data, and average values mask variation among stands, a significant amount of the tree remains on site to decompose or be burned as logging residue (Smith et al. 2006). At the mill, an additional component of the harvested wood becomes residue from producing the end product. In addition, transportation of the wood to the mill and market uses carbon. Therefore, the carbon stored in wood products over their lifetime, and potentially for some time after in a landfill, is a fraction of the carbon in living trees. Over the last several decades, carbon losses from logging outpaced carbon losses by fire on a per unit area basis in the western United States. For example, in the western United States from 1984 through 2020, carbon emissions from harvest of mature trees were 2 to 8 times greater per unit area than from wildfires larger than 1,000 acres (405 hectares) with at least 50 percent forest cover within the perimeter (Bartowitz et al. 2022).

Mature and older trees and forests generally store more carbon than younger forests. Models suggest that 120 years following harvest, a harvested mature forest and its associated wood products contain less carbon than a comparable, unharvested mature forest (Law et al. 2022). On public forests in Oregon, projected increases in the harvest rotation from 40 to 80 years, in conjunction with projected halving of harvest levels, would store considerably more carbon than planting trees in previously forested or unforested areas (Law et al. 2022). Averaged among 48 plots in undisturbed primary or older secondary forests worldwide, half of the aboveground biomass was in the one percent of trees with the largest diameter (Lutz et al. 2018). In six National Forests in the eastern Cascade Range and Blue Mountains in Oregon, Washington, and Idaho, an average of three percent of five species of trees had diameters of 21 in. (0.5 m) or greater, and stored about 42 percent of the aboveground carbon (Mildrexler et al. 2020).

Invest in the Fire Workforce of the Future

Many of the European-American settlers who colonized the western United States viewed fire as a destructive force to be controlled and eliminated. In the 1850s, state and federal governments outlawed Indigenous fire practices that had been used for thousands of years. After World War II, surplus military equipment was deployed to augment fire suppression. This increased investment coincided with a cool, wet period from the 1940s to the 1980s (Figure 3) and contributed to the belief that fire could be controlled if enough people and money were dedicated to doing so.

Thinning of shrubs, saplings, and the lower limbs of large trees can help prepare the ground surface of dry forests for the controlled reintroduction of fire by Indigenous, cultural, and prescribed-fire practitioners. This kind of understory thinning more often resembles pruning than removal of trees, and is generally followed by pile and broadcast burning where dead limbs and needles accumulate. The combustion of the surface and understory fuels provides nutrients for new plant growth (WFMMC 2023). The use of intentionally ignited fire is growing in Oregon. For example, Indigenous fire practitioners are reintroducing fire to the Willamette Valley, Southern Oregon, and the Klamath Basin. Oregon Senate Bill 762 (2021) required the Oregon Department of Forestry to establish a Certified Burn Manager Program that includes certification requirements, standards, and procedures and reduces individual liability for certified personnel who start prescribed burns consistent with legal and program criteria.

A number of organizations in Oregon offer workforce training. For example, the Lomakatsi Restoration Project works with tribes and agencies to implement ecosystem restoration projects and build a tribal workforce in the process. The Northwest Youth Corps established the Community Wildfire Protection Corps, which trains and employs people to reduce fire risk in high priority areas in and around communities. The Northwest Youth Corps crews focus on clearing vegetation in a buffer zone around infrastructure and homes. The organization works in coordination with local fire departments, Oregon Department of Forestry, and Office of State Fire Marshal.

Protect Aquatic Systems and Soils After Fire

Fires of all severities are natural ecosystem processes (Lindenmayer et al. 2004). Species richness and abundance of some taxa, including the abundances of some species of birds, often increases in the first few years after a wildfire (Smucker et al. 2005). Whether to log fire-damaged and fire-killed trees (Figure 7) has been debated for decades. Post-fire logging, especially in systems with sustained human activity and near streams, creeks, and rivers, can increase soil compaction and erosion


Figure 7. Logging following a wildfire. Photograph courtesy of ElementalFilm.com.

(McIver and McNeil 2006, Slesak et al. 2015, Wagenbrenner et al. 2015, 2016), increase sediment loads in waterways (Emelko et al. 2011, Silins et al. 2014), adversely affect habitat for some aquatic species, and hinder regeneration of some plant species (Karr et al. 2004). These effects result from both removal of trees and the infrastructure necessary for timber harvest, such as road building, vehicle traffic, and use of heavy machinery.

Effects of post-fire logging on soil nutrients, soil microbial and fungal communities, and carbon exchange capacity are difficult to distinguish from effects of the wildfire, which often are greater. However, in mixed-conifer forests in central Oregon, nutrients that contribute to soil productivity decreased in response to mechanical, post-fire timber harvest (Jennings et al. 2012). In mixed-conifer forests in the Sierra Nevada, post-fire logging reduced carbon storage, and carbon storage in mineral soil was particularly low in tree plantations that were logged following fire (Powers 2013).

Post-fire logging usually is a short-term economic decision, but can have long-term ecological impacts. Retaining dead, dying, and living trees in burned areas can contribute to conservation of water quality, commercially harvested fishes, and other aquatic species. Converting burned forests to tree plantations without dead wood increases the extent of a homogenous vegetation type that is well-represented in western Oregon, and the potential for high-severity fire (Zald and Dunn 2018). Furthermore, forests with diverse tree species are expected to tolerate climate extremes and other disturbances more effectively than monocultures, and to store carbon for longer (Osuri et al. 2020).

Harness Technology to Support Situational Awareness and Action

Community-level preparation for wildfire can benefit from technologies that provide accurate, timely, and actionable data. For example, real-time data on fire ignitions, spread, weather, and evacuation orders inform people about rapidly developing events. A growing number of companies and nonprofit organizations have devoted significant resources to predicting, detecting, mitigating, adapting to, and communicating about fire. These entities are capitalizing on satellite remote sensing data, drones, and artificial intelligence. Some of the tools and technologies are reliable and are being rapidly adopted, whereas others require further scrutiny.

Users of remote sensing data relevant to wildfires include the general public, media, federal and state agencies, and insurance and utility sectors. Satellite remote sensing provides information on the environmental characteristics that affect fire probability, wildfire behavior, the extent and recovery of burn areas, post-fire erosion, and impacts on air and water quality. Satellites deployed by the National Aeronautics and Space Administration and operated by the National Oceanic and Atmospheric Administration provide real-time weather and fire weather forecasting capabilities.

To facilitate parcel-level mitigation and ideally reduce the risk of insuring homes, entrepreneurs have developed tools that allow fire departments to directly assess home flammability and provide homeowners with clear, actionable recommendations. For example, Fire Aside developed software to enable firefighters to efficiently assess a home's preparedness for fire. The software allows an expert assessor to quickly provide a homeowner with a prioritized list of potential actions, grant opportunities, and a simple mechanism for reporting steps taken. Fire Aside has been adopted in Ashland and Eugene, Oregon, and is under consideration by other jurisdictions in the state. The Fire Aside defensible space report also is being used by about 70 percent of homeowners in Truckee, California, to identify defensible space and home-hardening actions and to qualify for discounts on insurance premiums.

For the last two decades, the public and the media have relied on Inciweb, an interagency, all-risk incident information management system that provides data on active fires. In recent years, people also have turned to social media. In some cases, the information from social media is outdated, inaccurate, and rife with conspiracy theories. To illustrate constructive responses to this reality, in 2022, Watch Duty launched a mobile application to provide real-time, accurate information on fires, including alerts, fire perimeters, and images from live cameras. Watch Duty's information comes from a team of firefighters, dispatchers, and reporters who monitor radio scanners around the clock. Watch Duty Pro, which is available to firefighters and first responders, includes information on land ownership, evacuation zones, radio repeaters, critical infrastructure, and utility service territories.

As another innovative example, with the aim of reducing the risk of ignitions from power generation, transmission, or distribution, Gridware has engineered a sensing system that monitors overhead power infrastructure. The system detects and identifies disturbances such as vegetation strikes on power lines, fallen lines, broken poles, and conductor clashes and reports them to the utilities. The tool is intended to increase safety and reduce outage durations by providing information even when the electrical system is down.

A Vision for the Future

Shifting from a societal perspective that all fires are harmful to fire-resilient communities requires understanding of the dominant influences on wildfire ignition and behavior and strategic investment in wildfire mitigation. To make this shift, scientists and firefighters are encouraging the public to make homes and communities resistant to fire rather than attempting to control the flammability of vegetation across vast areas. Home mitigation specialists, landscapers, architects, and builders are supporting homeowners to prepare structures to resist ignition. Public agencies, firefighters, and legislators are supporting prescribed burn associations. Companies are harnessing existing technology and developing new tools that provide people with situational awareness and analysis before, during, and after fires.

Elemental: Reimagine Wildfire was produced to help people learn to live within the natural realities of fire. During our nationwide tour, teachers, students and firefighters asked our film team if we were aware of any curricula on wildfire-prepared homes. We were not, and therefore hired an experienced curriculum developer to prepare the peer-reviewed *We Live With Fire* curriculum. The curriculum is adaptable for grades 6–12, undergraduates, and the general public. It focuses on what people can do to design, build, retrofit, and maintain homes and communities to be fire-ready and fire-safe.

The *We Live with Fire* curriculum and *Elemental: Reimagine Wildfire* are part of a larger, collective effort by firefighters, fire survivors, tribes, utilities, businesses, legislators, non-profit organizations, philanthropists, and others to set Oregon on a new path. In this envisioned future, Oregonians understand that fire is inevitable and can be beneficial, and are prepared for fire and smoke.

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