

Science

FINDINGS

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“Science affects the way we think together.”
 Lewis Thomas

Beyond Burn Probability: The Human Side of Wildfire Risk



The 2017 Eagle Creek Fire. This fire in the Columbia River Gorge National Scenic Area was human-caused, as were 73 percent of all wildfires in western Oregon and Washington from 1992–2018. Photo by Curtis Perry/Flicker.

IN SUMMARY

Across the Pacific Northwest’s fire-prone landscapes, where human activity accounts for about 58 percent of all ignitions, socioeconomic factors point to why some communities face repeated blazes and some remain untouched. These patterns raise critical questions about the allocations of wildfire resources.

After analyzing more than 104,000 wildfire ignitions across Oregon and Washington from 1992–2018, researchers Jeff Kline, Mindy Crandall, and Caitlyn Reilley reveal a paradox in wildfire risk management. While current risk assessment tools predict higher wildfire hazard in well-resourced communities, some socially vulnerable communities actually experience more fires.

Human activities caused 73 percent of ignitions west of the Cascades and 48 percent east of the Cascades. Recreation and open debris burning represented the largest sources at 32 and 24 percent, respectively. Most ignitions involved discretionary behaviors—intentional fire use that could be influenced by prevention efforts.

The researchers found that traditional risk models based on biophysical factors like vegetation, terrain, and weather miss crucial human factors. Current resource allocation based on such models may inadvertently contribute to inequities by directing risk mitigation funding toward areas that appear risky on paper but experience fewer actual fires. Integrating social vulnerability into risk assessment could create predictions that more effectively consider the community’s vulnerability, ensuring that resources reach communities facing the greatest fire burden.

*All that you touch you change.
 All that you change changes you.*

—Octavia Butler, American author

Imagine a high desert or mountain resort community in eastern Oregon or eastern Washington in the middle of a hot, dry summer—blue sky and sun blazing down on vacation cabins surrounded by dense ponderosa pine forests, needles crunching underfoot.

“Drop a match and boom, the place is going up,” says Jeff Kline, a retired research forester and economist with the Forest Service’s Pacific Northwest Research Station. “It’s a powder keg.”

A single moment of ignition—a match, cigarette, an ember or spark from a campfire or equipment—marks the boundary between risk and reality. These ignition points scatter across the landscape in patterns shaped by weather, human activity, infrastructure, and social context. Humans cause most wildfires globally and nationally. This means prevention efforts that target the actions leading up to human-caused ignitions may be the most efficient approach to managing wildfire. Since Smokey Bear first appeared in 1944 urging Americans to prevent forest fires, the importance of human behavior in wildfire prevention has only grown more critical.

Yet sophisticated risk assessment tools that forecast wildfire behavior and guide substantial risk mitigation investments focus primarily on biophysical conditions—vegetation, topography, and weather.

“What these models are not accounting for is the human factor,” says Kline.

Communities differ not only in their exposure to wildfire hazards but also in their capacity to prepare for, respond to, and recover from them. This varying capacity, often referred to as social vulnerability, stems from factors like income levels, age demographics, housing quality, and access to resources to help mitigate fire risk—factors that remain largely absent from traditional risk assessment frameworks.

“As the Northwest faces bigger and more intense fires, and as more people live closer to fire-prone forests—or forests that might become fire prone—the focus has been how to mitigate wildfire risk,” Kline says. “But there’s another question to consider. Is there anything we can do about how wildfires start, and whether or not they spread?”

Kline partnered with Mindy Crandall, associate professor of forest policy at Oregon State University, and her graduate student at the time, Caitlyn Reilly, to answer questions at the intersection of the biophysical and human worlds. Questions like: what are the main causes of wildfire ignitions, and what role does social vulnerability play in the predicted and actual wildfire experience of communities in Oregon and Washington?

PNW Science Findings

Providing scientific information to people who make and influence decisions about managing land.

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
USDA Forest Service
1220 SW 3rd Ave., Suite 1400
Portland, OR 97204

Send new subscription and change of address information to:

SM.FS.pnw_pnwpubs@usda.gov

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KEY FINDINGS

- Wildfire data from 1992–2018 indicate that human causes account for 73 percent of all wildfires in western Oregon and western Washington. In eastern Oregon and eastern Washington, human and natural ignitions are roughly even, at 48 percent and 51 percent, respectively.
- “Recreation and ceremony” and “debris and open burning” account for more than half of human-caused wildfires. These types of ignitions, along with vehicle use, smoking, and fireworks, are discretionary behaviors that, conceivably, are within human control.
- Income, employment, population density, and housing were significantly correlated with human-caused ignitions in some regions, suggesting that socioeconomic context plays a role in these ignitions.
- Socially vulnerable communities generally were in areas with lower wildfire risk, whereas wealthier, amenity-rich communities were often located in fire-prone landscapes. However, socially vulnerable east side communities were more likely to experience ignitions, escaped fires, and large fires.

“There’s how people and communities experience wildfire, and then there’s how fires start, people’s behavior,” Crandall says. “It’s not only about treating the forest. It is also about addressing the human part of the equation.”

Prevention efforts targeting common ignition sources, mitigation investments enhancing community resilience, and response strategies protecting vulnerable populations all require a more comprehensive approach that integrates both biophysical and socioeconomic factors into wildfire risk assessment and management.

Ignition patterns

Drawing on analysis of more than 104,000 wildfire ignitions spanning nearly three decades, the scientists reveal how the complex interplay between human activity and wildfire ignition does not distribute risk equally across society or across regions.

“Essentially, eastern Oregon is more flammable, drier, but western Oregon is more populated,” Crandall says.

The Cascade Range divides the region’s wildfire ignition patterns into distinct regimes. On the west side, where 82 percent of the region’s residents live, human activity dominates ignitions at 73 percent. On the east side, human activity accounts for 48 percent of ignitions and lightning strikes 51 percent.

Identifying the primary human ignition sources of wildfires shows that most stem

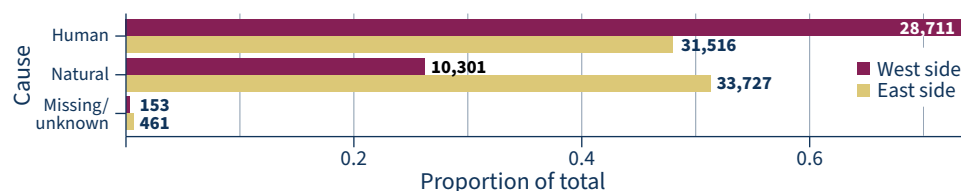
from discretionary activities—those involving an intentional choice to take an action that risks starting a wildfire—that strategic, targeted prevention efforts could influence.

Across the Pacific Northwest, recreation and ceremony account for nearly a third (32 percent) of all human-caused ignitions. These include campfires, fireworks, and ceremonial burns that escape control. The popularity of outdoor recreation in the region’s scenic forests means this category creates an outsized risk, especially during summer months when campgrounds fill with visitors unfamiliar with local conditions.

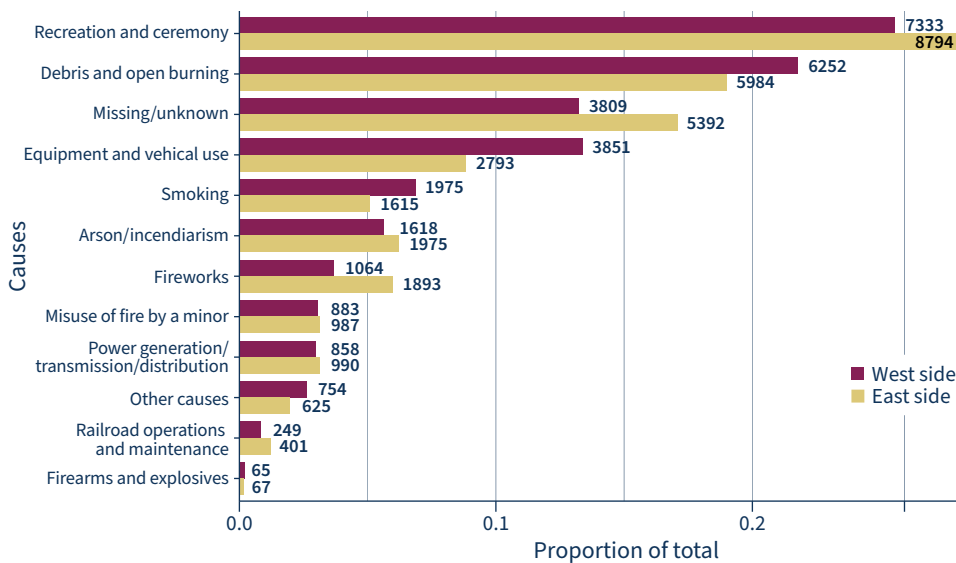
Open burning to clear brush, burning yard waste, or conducting agricultural burns that escape containment represent 24 percent of human ignitions throughout the Pacific Northwest, with a higher proportion in rural areas where such practices are common.

The third most common source comes from equipment and vehicles, accounting for 13 percent of ignitions on the west side and 9 percent on the east side. Sparks from chainsaws, tractors, or vehicles traveling on dry grass or dragging trailer chains can ignite nearby vegetation. This category had a higher concentration in southwestern Oregon, where forestry operations intersect with seasonally combustible landscapes.

Together, these three categories represent more than half of all human-caused ignitions with known causes and pose the greatest risk to communities across the region.



From 1992–2018, human-caused fires accounted for a higher proportion of fires west of the Cascades in Oregon and Washington, whereas natural fires accounted for a higher proportion of fires on the east side. Adapted from Reilly et al. (2023).



Types and frequency of ignition sources in Oregon and Washington, 1992–2018. Adapted from Reilley et al. (2023).

Most human ignitions involve discretionary behaviors that are within human control. Roasting marshmallows over a campfire, for example, is a choice.

“I was surprised by how much intentional behavior causes wildfire,” Crandall says. “Because in my mind, wildfires were caused by accidental things, like throwing a cigarette butt out the window, or parking a car’s hot tailpipe on dry grass.”

Those types of “accidental” ignitions are considered indirect or unintentional behavior—not a result of a conscious choice.

“We’re making a tradeoff, whether we realize it or not,” Kline says. “When we choose to use fire, then we have to accept the risk, that fires can escape and may turn into big wildfires.”

Pat Erdenberger says she was stunned to learn how many wildfires are caused by humans,

including from backyard burning and campfires. “So often people feel it’s fate,” she says.

As chair of the Hoodland Community Planning Organization, she was among 50 or 60 people who gathered at a local pub one evening in Welches, Oregon, to learn about wildfire ignitions from Kline.

“Our demographic includes many retired professionals who are eager to hear about the latest studies in this area of focus,” Erdenberger says.

She says many homes in the area are either second homes or short-term rentals. In her opinion, those homeowners could also benefit from the ignitions information.

“When I talked with the group,” Kline says, “I realized this group was the local fire department, the regional office of the Forest Service, community members, and land use

planners meeting together to try to figure out how to address wildfire risk.”

Erdenberger says no other topic spans all groups of people in the region and that the community is aware of the risks associated within the wildland-urban interface. Yet many in the region think wildfires are predominantly started by lightning.

“That we have some control, was so important for everyone to hear,” she says. “We don’t have to just hope for the best, there are specific things we can do to prevent wildfires.”

Social factors shape wildfire risk

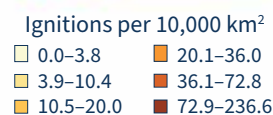
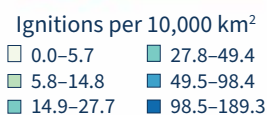
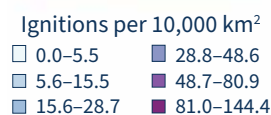
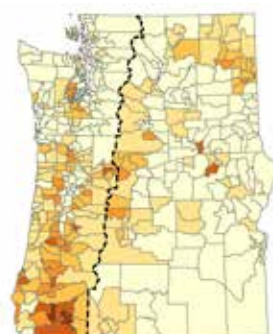
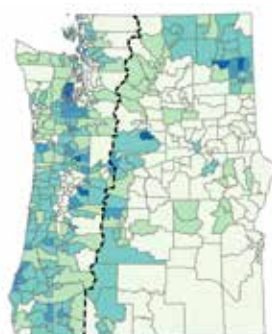
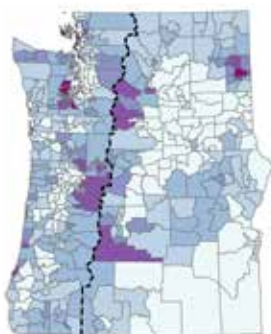
The frequency of ignition sources varies based on community socioeconomic characteristics. Some socioeconomic factors show consistent patterns across regions. Age demographics play a crucial role. Communities with higher proportions of residents over 65 experienced fewer ignitions regionwide. Older residents likely engage less frequently in high-risk behaviors, such as lighting fireworks or operating equipment, that could produce sparks. Higher median household incomes were associated with increased human ignitions across both sides of the Cascades.

More human-caused ignitions occurred in areas with more people, although this relationship was stronger on the west side than on the east side where natural ignitions dominate. Some socioeconomic factors produced opposite effects, depending on the region: ignitions on the west side were more prevalent in areas with unoccupied, seasonal housing but less prevalent in similar areas east of the Cascades, likely reflecting different patterns of seasonal use. Greater unemployment correlated with fewer ignitions in west side communities but with more in east side communities.

A. Recreation and ceremony

B. Debris and open burning

C. Equipment and vehicle use



Geographic patterns by county of the top three known causes of human wildfire ignitions—(A) recreation and ceremony, (B) debris and open burning, and (C) equipment and vehicle use—west and east of the Cascades Range in Washington and Oregon, 1992–2018. Adapted from Reilley et al. (2023).

The complex relationship between socioeconomic factors and wildfire ignitions uncovered by this study illustrates why one-size-fits-all prevention approaches often fall short in addressing human-caused ignitions. Instead, prevention strategies that account for both the dominant ignition sources in a region and the unique socioeconomic context that influences human behavior and fire risk are likely to be more effective.

Rethinking wildfire risk assessments

The regional patterns of ignition sources and socioeconomic drivers tell only part of the story. A striking contradiction emerged when the scientists compared predicted wildfire risk with what communities actually experience across the Pacific Northwest.

LAND MANAGEMENT IMPLICATIONS

- The prevalence of human-caused ignitions, coupled with the percentage arising from discretionary behaviors such as recreation and debris burning, point to opportunities for tailoring wildfire prevention and education efforts to better manage higher risk discretionary ignitions.
- Burn permitting application processes are one opportunity for disseminating information to landowners about wildfire risk and accidental escape.
- Integrating social vulnerability metrics into formal risk assessment frameworks could create more accurate predictions of fire experience and help direct resources where they're most needed.
- Wildfire management strategies that account for varying community resource levels could improve both vegetation management practices and early fire detection capabilities by recognizing that different communities have different capacities. Such tailored approaches could be more effective because they consider how social factors (like community resources) interact with environmental factors across all types of wildfires, not just those directly started by people.

Current wildfire risk maps—showing burn probability, hazard potential, and risk to homes—consistently place communities with higher social vulnerability in lower-risk categories. These sophisticated models excel at capturing physical factors like vegetation, terrain, and weather, but miss crucial human dimensions that shape real-world fire patterns.

When the scientists analyzed three decades of actual fire records, they discovered the opposite of what models predicted. After accounting for environmental factors, communities facing greater socioeconomic challenges experienced more fires. This gap was most pronounced east of the Cascades: modeling results indicated that a 10-point increase along the social vulnerability index meant communities faced 4 percent more ignitions, 6 percent more escaped fires, and 3 percent more large burns.

Kline explains that this gap exists primarily because current risk assessment tools assume all communities have equal fire prevention and response capabilities. They don't recognize that rural fire departments often rely on volunteers and aging equipment, or that communities with limited resources struggle to maintain defensive space and conduct prevention activities.

As a result, resource allocation decisions may become misaligned. Risk mitigation funding may flow toward places that look risky from current fire models but experience fewer actual fires, while vulnerable communities may receive inadequate support despite greater need. Wealthier communities more likely can supplement mitigation funding with their own resources and recover more easily from fires, while poorer communities face more fires but have less funding for both prevention and recovery.

Environmental factors—humidity, road density, forestland coverage, and suppression difficulty—still strongly influence where fires occur. Yet even after accounting for these physical variables, social vulnerability remained a significant predictor of fire exposure, particularly east of the Cascades.

The research suggests that socioeconomic factors, such as income, employment, population density, and housing, act as risk multipliers. Vulnerable communities face a double challenge: more fire starts from activities like recreation and debris burning alongside less capacity to contain them. This combination means small fires more often grow into large, destructive blazes, hitting already disadvantaged populations the hardest.

Redesigning wildfire risk assessment so that socioeconomic factors are integrated alongside physical variables could create more accurate risk measures and direct resources toward communities truly experiencing the greatest fire burden.

The disconnect between predicted wildfire risk and actual community fire experience points toward opportunities for improvement, such as addressing discretionary behaviors that lead to human ignitions and reconsidering how wildfire risk is assessed and managed.

The prevalence of human ignitions, coupled with how many are sourced to discretionary behaviors such as recreation and debris burning, offers significant opportunities for tailoring wildfire prevention and education efforts. These two categories alone account for 56 percent of all human-caused ignitions across the Pacific Northwest. Prevention strategies focused specifically on these high-risk activities could yield substantial reductions in fire starts.

Burn permitting systems could be adjusted regionally to reflect different ignition patterns east and west of the Cascades, with timing restrictions based on local conditions. These permitting processes also provide opportunities for wildfire risk education, reaching individuals when they're planning potentially risky activities.

Communities with different resource levels may manage vegetation differently or have varying capacities for detecting and responding to ignitions before they develop into larger fires. This finding underscores the complex interplay between social and biophysical factors across all aspects of

Firefighters work to extinguish an escaped campfire that had been illegally ignited during a burn ban and then abandoned in the Coconino National Forest, Arizona. USDA Forest Service photo.

wildfire, not just those directly caused by human activity.

Current reliance on biophysical data in wildfire risk assessment overlooks the crucial role that social vulnerability plays in determining community risk. Communities with higher social vulnerability consistently experience more fires despite showing lower scores on traditional risk metrics.

This disconnect has potential social equity implications. Integrating social vulnerability metrics into formal risk assessment frameworks could create more accurate predictions of fire experience and help direct resources where they're most needed.

Such integration could enhance readily available census data on income, age demographics, and housing patterns—the same factors that influence actual fire patterns across the Pacific Northwest.

A more complete story

The gap between predicted wildfire risk and actual community exposure reveals important drawbacks to how wildfire resources are allocated. These flaws may leave vulnerable communities bearing a disproportionate burden of wildfire impacts.

As communities continue to expand in fire-prone landscapes, understanding these socioeconomic dimensions becomes increasingly urgent. Addressing human-caused ignitions, particularly those from discretionary behaviors, offers promising avenues for reducing overall fire occurrence. Equally important is integrating social vulnerability metrics into risk assessment to ensure that resources flow to communities experiencing the greatest actual fire burden.

The story of wildfire in the Pacific Northwest is more complex than burn probabilities alone. It includes human dimensions that shape both risk and resilience—the socioeconomic factors that determine not just who can recover from disaster, but who experiences it in the first place. As society learns to coexist with fire, ensuring that communities are resilient is essential.

“Only you can prevent wildfires.”

—Smokey Bear

Writer's Profile

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Crews use prescribed fire to reduce fuels near homes in western Oregon. USDI Bureau of Land Management photo.

Further reading

Kline, J.D.; Ager, A.A.; Fischer, A.P. 2015.

A conceptual framework for coupling the biophysical and social dimensions of wildfire to improve fire management and risk mitigation. Proceedings of the 13th International Wildland Fire Safety Summit & 4th Human Dimensions of Wildland Fire Conference. Missoula, MT: International Association of Wildland Fire: 204–212. <https://research.fs.usda.gov/treesearch/52508>.

Reilley, C.; Crandall, M.S.; Kline, J.D. [et al.]. 2023. The influence of socioeconomic factors on human wildfire ignitions in the Pacific Northwest, USA. *Fire*. 6(8): 300. <https://doi.org/10.3390/fire6080300>.

Reilley, C.; Dunn, C.J.; Crandall, M.S.; Kline, J.D. 2024. Socially vulnerable US Pacific Northwest communities are more likely to experience wildfires. *Environmental Research Letters*. 19(9): 094053. <https://doi.org/10.1088/1748-9326/ad6ccc>.

Wigtil, G.; Hammer, R.B.; Kline, J.D. [et al.]. 2016. Places where wildfire potential and social vulnerability coincide in the coterminous United States. *International Journal of Wildland Fire*. 25(8): 896–908. <https://research.fs.usda.gov/treesearch/52233>.



Smokey reminds forest users of their role in preventing forest fires. USDA Forest Service photo.



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