HENRY M. JACKSON SCHOOL OF INTERNATIONAL STUDIES

UNIVERSITY of WASHINGTON

TASK FORCE

The Donald C. Hellmann Task Force Program

A Hot Topic: Causes, Impacts, and Solutions to the Wildfire Issue in the Western United States

Sullivan, Justin. "The Camp Fire Moves through the Area in Paradise, California, on Nov. 8, 2018." *NBC News*, NBC News, 23 Mar. 2020, www.nbcnews.com/news/us-news/pg-e-plead-guilty-manslaughter-california-camp-fire-n1166471.

2021

Thanks to Prof. Daniel Jaffe, Prof. Brian Harvey, and Crystal Raymond, PhD.

Dedicated to Prof. Scott L. Montgomery: Thank you for your patience, support, and constant fight to tackle the beast that is teaching through Zoom.

Table of Contents

Glossary

Algae bloom:

These can produce extremely dangerous toxins that can sicken or kill people and animals, and create dead zones in the water.

Ammonia:

Ammonia (NH3) is found throughout the environment in the air, soil, and water, and in plants and animals, including humans. Ammonia is also found in many household and industrial cleaners. High levels of ammonia can irritate and burn the skin, mouth, throat, lungs, and eyes. Very high levels of ammonia can damage the lungs or cause death.

Anthropogenic:

Of, relating to, or resulting from the influence of human beings on nature.

Benzene:

A highly flammable, colorless liquid that evaporates quickly into the air and is harmful to the eyes, skin, airway, nervous system, and lungs. It can also cause blood cancers like leukemia.

Bronchial epithelial cells:

These are isolated from the surface epithelium of human bronchi and stain positive for cytokeratin. The respiratory epithelia are responsible for the lubrication of the lungs, the maintenance of humidity, and the cleaning of the respiratory tract and are an important target for drugs, toxins, and carcinogens.

Bureau of Land Management (BLM):

A part of the United States Department of the Interior responsible for overseeing federal lands.

Carbon Monoxide:

A colorless, odorless, tasteless, and poisonous gas. Breathing in carbon monoxide is poisonous and can often be fatal. When an individual is exposed to too much carbon monoxide, it will destroy his/her oxygen absorbing capacity and cause serious damage to the tissues (due to a lack of oxygen).

Community Planning Assistance for Wildfire (CPAW):

Works with communities and provides land use planning solutions to better manage their wildland-urban interface.

Community Wildfire Protection Plan (CWPP):

A community-based plan that identifies local wildfire risk, what is at risk, and actions the community must take to address its wildfire risk.

Cytokines:

Small proteins that are crucial in controlling the growth and activity of other immune system cells and blood cells and when released, they signal the immune system to do its job.

Federal Emergency Management Agency (FEMA):

Supports citizens and first responders to build, sustain, and improve our capability to respond to, recover from, and mitigate all hazards.

Formaldehyde:

A colorless pungent gas in solution made by oxidizing methanol that can be an irritant of skin, eyes, nose, and throat and some authorities consider formaldehyde to increase the risks of certain types of cancer in people.

Health Forests Restoration Act (HFRA):

Signed into law in 2003, intended to reduce the threat of wildfires while upholding environmental standards. Also encourages public input early on in the planning process.

Home ignition zone (HIZ):

Also called defensible space, is the area 30- 100 feet from the foundation and includes vegetation, the home itself, and other structures or attachments like decks, furniture, fences, and outbuildings.

Horizontal Spacing:

The cutting of tree branches in the canopy to prevent crowding between trees.

Hydrogen cyanide:

A colorless or pale-blue liquid or gas with a bitter, almond-like odor. Hydrogen cyanide interferes with the body's use of oxygen and may cause harm to the brain, heart, blood vessels, and lungs. Exposure can be fatal.

Hydrogen sulfide:

A chemical compound with the formula H 2 S. It is a colorless chalcogen hydride gas with the characteristic foul odor of rotten eggs. It is poisonous, corrosive, and flammable.

International Code Council (ICC):

An association dedicated to building safety and fire prevention.

International WUI Code (IWUIC):

A model code that is intended to be used as supplement along with the adopted building and fire codes of a jurisdiction.

Macrophages:

Specialized cells involved in the detection, phagocytosis and destruction of bacteria and other harmful organisms.

Manufactured Housing Units (MHUs):

Prefabricated housing units used for displaced residents to temporarily reside in

Microbes:

Microbes, or microorganisms, include bacteria, protozoa, fungi, algae, amoebas, and slime molds.

Overlay Zoning districts:

A regulatory tool that creates a special zoning district on top of the original base zone. It identifies special provisions in addition to those in the underlying base zone.

Partial oxidation (POX):

Partial oxidation, or gasification, is a chemical reaction that occurs when a mixture of a hydrocarbon feedstock and a sub-stoichiometric amount of pure oxygen are reacted together, producing a syngas stream.

Phosphorous:

Phosphorus definition is - of, relating to, or containing phosphorus especially with a valence lower than in phosphoric compounds.

Prescribed burn:

Intentional fire set to burn vegetation and underlying growth of a forest.

Pruning:

Selective removal of certain parts of a plant, regrowth unlikely.

Resource Protection Overlay Zone (RPO):

A specific overlay zone in place in Flagstaff, Arizona with the goals of protecting the natural resources in the escarpments.

Spatial Connectivity:

Vegetation growth that connects forests and thereby increases wildfire transmission.

Thinning:

Removal of trees to promote overall growth and mitigate the spread of wildfires.

Trimming:

The cutting of branches to promote healthy growth.

United States Forest Service (USFS):

A part of the U.S. Department of Agriculture that oversees the nation's 154 national forests and 20 national grasslands.

Vertical Spacing:

The cutting of tree branches and vegetation at least 6 feet above the ground.

Wildland-Urban Interface (WUI):

A zone between wildland and human development where houses meet or intermingle with undeveloped wildland vegetation. The most at risk community for wildfire threats.

Executive Summary

Kristian Whittaker

This past year, 2020, was the most active on record for wildfires in the West Coast of the United States. It broke (or came close to breaking) records in terms of land burned, fires reported, damage caused, and lives lost[1]. The economic consequences of these high severity fires were felt by hundreds of thousands, the health consequences of the toxin-laden smoke by millions more. And 2020 was not a one off. Instead, it was the most recent high point in a decades' long trend of increasing wildfire size, severity, duration, and damage. A century of fire suppression, rising temperatures and longer fire seasons due to climate change, as well as continued growth along the urban/rural frontier have together increased the risk of more deadly infernos. It is now estimated that wildfire risk in 2040 will be four times greater than during the period of 1980 – 2006. However, with a shift from reactive to proactive approaches in dealing with such risk, a good deal of mitigation can be achieved. In addition to physically reducing risk where possible, this would involve raising public awareness further, increasing research into wildfire-related issues, and improving communication among stakeholders. With these and other efforts going forward, the West Coast can learn how to live with wildfires.

During our research, the overarching theme we found was that wildfires are not going anywhere. They have been an integral part of the American West for thousands of years, and have played key roles in shaping biomes across the region; from the thin pine and oak forests of Eastern California to the dense rainforests of Western Washington. Over the last century, pioneers and their descendants came to believe that they could suppress the chaos and danger of wildfires without consequence, and today our generation is paying the price for their arrogance. In a way, wildfires are simply the first of the climate change related issues; born of the previous generations' hubris, it is our generation that must find a way to live with them.

To do so, our Task Force has taken a deep dive into all things wildfire related, and we've broken our report into the following sections, each with several chapters contained therein; Historical Wildfire Trends, Consequences of Fire, Risk Mitigation and Fire Prevention, Current Fire Management, and Policy Recommendations. Our specific chapters looked at problems such as issues with smoke and particulate matter, the impact of climate change on wildfires, the dangers (and best practices) for living in the Wilderness-Urban Interface (WUI), limitations of

---

[1] https://www.nytimes.com/interactive/2020/09/24/climate/fires-worst-year-california-oregon-washington.html

current solutions, fuel treatment practices, and more. After we completed our research, we put together a list of policy recommendations including:

- Further research regarding smoke and its impact on public health
- Increased funding for lower socioeconomic strata affected by wildfire.
- Implementation of environmental protection measures in areas of high PPM concentration.
- Implementation of outreach and awareness campaigns regarding smoke, living in the WUI, living with wildfires, prescribed burns, fuel treatment, etc.
- Shifting funding from reactive to proactive firefighting techniques.
- Further research into fuel treatment methods and which contexts these methods suit the most
- Implementation of fire safe building/ renovating codes and material quotas for the WUI.
- Establishing better management of state and private utilities commissions.
- Implementation of better communication channels between various state, local, and federal institutions, and standardized economic damage planning.
- Further research on climate change and how it will impact wildfires.

The tools needed to lessen the economic and human costs of wildfires already exist, but simply aren't being implemented to the extent that is necessary. Preventative measures such as prescribed burns, public awareness campaigns explaining to WUI residents the dangers of their lifestyle, and social programs to help homeless off the streets when PPM levels are dangerous all exist, yet are outweighed by policymakers on both sides of the aisle throwing up their hands at what they call "natural disasters." We believe that the paradigm surrounding wildfires needs to evolve in order to better defend communities both near and far from wildlands. Allocating funding to preventative measures and implementing policies that support the fire regime rather than unrealistically suppressing it are the first steps to be taken.

Wildfire and Climate History

Jovenzo Legaspi

Introduction

Wildfires are a natural event in ecological domains of the U.S. West Coast, yet, after decades of suppression by humans, they have grown in size and severity to become a rising threat to people and wildlife throughout the region. Suppressing fires during most of the 20th century has led to an overabundance of fuel and a "fire deficit" in many forests. Yet other factors have also contributed to elevated risk. Climate change has brought rising temperatures and drier conditions to many parts of the region, which has had the effect, in turn, of making some species of trees more vulnerable to damage by insects. In addition, over the past several decades, an ever-growing number of people have moved into areas proximal or within forested lands in California, Oregon, and Washington. Taken together, these factors have created a situation in which the risks to public health and to built environments have increased quite rapidly since the 2000s. Most of the largest wildfires on record have occurred within just the past 15 years.

Major Historical Wildfires

Historical wildfires that have caused major economic damages have occurred more frequently within recent years, growing in size and intensity over the decades.

Wildfires within the Past

Wildfire potential along the west coast is becoming more frequent following a drier climatological cycle.[5] Combined with changes in precipitation and an accumulation of dead fauna, major wildfires can quickly migrate over into other states sharing borders along the western region.[2] In November of 2018, California experienced its deadliest wildfire at the time of record.[3] A wildfire that started in Butte County, California; Camp Fire was able to displace over 50,000 people.[4] The fire would continue to destroy 153,336 acres of Californian land.[5] California called for people to be evacuated, with many migrating to Chico, the largest city within the

---

[2] Crockett, Joseph L., and A. Leroy Westerling. " Greater Temperature and Precipitation Extremes Intensify Western U.S. Droughts, Wildfire Severity, and Sierra Nevada Tree Mortality". Journal of Climate 31.1 (2018): 341-354. < https://doi.org/10.1175/JCLI-D-17-0254.1>. Web. 26 Feb. 2021.

[3] Adam.Smith@noaa.gov. "Billion-Dollar Weather and Climate Disasters: Events." National Climatic Data Center, www.ncdc.noaa.gov/billions/events/US/2000-2020.

[4] "Forced from Paradise: Leaving Home after One of America's Deadliest Wildfires." *The Washington Post*, WP Company, 23 July 2019, www.washingtonpost.com/graphics/2019/national/paradise-fire-displaced-residents/.

[5] California Department of Forestry and Fire Protection (CAL FIRE). "2018 Incident Archive." Cal Fire Department of Forestry and Fire Protection, www.fire.ca.gov/incidents/2018/.

region.[6] With overstrained resources, Chico would be one of many cities facing shortages of resources due to the massive displacement and an increased 20% population.[12] Butte County had previously faced 2 previous wildfire incidents in 2008 and 2017, leading to a two year rehabilitation project for those affected.[7] California also endured its largest and most destructive wildfire on record that year, the Mendocino Complex Fire burning over 459,000 acres and destroyed more than 18,000 buildings.[8] California was once again hit with 2 additional wildfires in both Northern and Southern regions, the Carr Fire and Woolsey Fire. In total, the 2018 wildfires have costed California and other minor costs from Western states approximately $25 billion, setting a new U.S. record.[9] Over 2.8 million acres were burned across the U.S. and marking the past 2 years as having unprecedented wildfire damages with losses exceeding $40 billion.[9]

In 2020, the U.S. experienced its worst wildfire season with record breaking of more than 10.2 million acres burned.[9] California more than doubled its 2018 record of area burned. The August Complex was the largest wildfire California has experienced to date, beginning as 37 separate wildfires within Northern California's Mendocino National Forest after numerous lightning strikes.[9] Approximately 10,500 buildings were destroyed and damaged across California, and over 1 million acres burned.[15] The August Complex started in mid-August was finally contained in early November, costing at least an estimated $166 million in damages.[10]

Different Perspectives Regarding Fire

In comparison to Native and Modern-day Americans, the role of fire has been contradictory when compared between the two.

---

[6] "Newsletter: How the Camp Fire Reshaped a Town Where Nothing Burned." *Los Angeles Times*, Los Angeles Times, 8 Nov. 2019, www.latimes.com/california/story/2019-11-08/camp-fire-chico-california-newsletter.

[7] "Butte County Fire Burns 30 Homes; 9,000 Flee." *Los Angeles Times*, Los Angeles Times, 13 June 2008, www.latimes.com/archives/la-xpm-2008-jun-13-me-fires13-story.html.

[8] California Department of Forestry and Fire Protection (CAL FIRE). "2018 Incident Archive." *Cal Fire Department of Forestry and Fire Protection*, www.fire.ca.gov/incidents/2018/#:~:text=The%20Mendocino%20Complex%20Fire%20burned,California's%20single%2Dlargest%20recorded%20wildfire.

[9] InciWeb developed and maintained by USDA Forest Service, Fire and Aviation Management. "August Complex." *August Complex Information - InciWeb the Incident Information System*, inciweb.nwcg.gov/incident/6983/.

[10] Gabbert, Author Bill. "August Complex Archives." *Wildfire Today*, 8 Dec. 2020, wildfiretoday.com/tag/august-complex/.

Native American Perspective

For most of modern-day America, fire has been considered a destructive force within nature.[11] What colonial America had seen in nature was an uncontrolled forest, yet those who knew better practiced prescribed burns rather than let fuel stockpile in the forests.[17] Extending back 10,000 years, fire was used by Native Americans traditionally as a control method to shape their surrounding environment.[12] Indigenous peoples used fire in a myriad of ways; hunting, management of crops, prescribed burns around settlements to enact a fireproof boundary, clearing of trade routes, and clearing of trees and areas near rivers.[18] The abundance of open grasslands is believed to be the result of fire management by Native Americans.[13] Within Yosemite Valley, evidence has been found to show that Native Americans have shaped the landscape within California by fire for approximately 4,000 years.[14] Following the colonization of the continent, however, the use of fire as a tool to shape the lands declined and forests began to cover these grasslands once again. The methods Native Americans used for thousands of years were overlooked as Europeans colonized more of the land and saw the use of fire as lesser.

Western Perspectives

In April 1910, following harsh drought conditions, the wildfire season started early on the west coast.[15] The U.S. Forest Service was established only 5 years prior, and believed that minor fires happening at the time were able to be mitigated and contained.[16] Though many small fires occurred across Idaho, Montana and Washington in the spring, it would be on August 22nd that hurricane-like winds further spread and combined smaller fires in order to form the Big Blowup.[17] Over its lifetime, the fire was able to burn over 3 million acres of land, leaving several communities destroyed and 85 people killed.[22] In the following years, the U.S. Forest Service adapted the “the 10 a.m. policy” in order to mitigate and snuff out ever wildfire that occurred

---

[11] Pyne, Stephen J. *Tending Fire: Coping with America's Wildland Fires*. Island Press for Shearwater Books, 2004.

[12] Raish, Carol, et al. “The Importance of Traditional Fire Use and Management Practices for Contemporary Land Managers in the American Southwest.” *Environmental Hazards. 6(2): 115-122*, 1 Jan. 1970, www.fs.usda.gov/treesearch/pubs/23871.

[13] Arno, Stephen F., and Stephen Allison-Bunnell. *Flames in Our Forest Disaster Or Renewal?* Island Press, 2013.

[14] “Wildland Fire: Cultural Interpretations of Fire and Human Use (U.S. National Park Service).” *National Parks Service*, U.S. Department of the Interior, www.nps.gov/articles/wildland-fire-human-use-and-cultural-interpretations.htm.

[15] NCEI.Monitoring.info@noaa.gov. “Climate at a Glance.” *National Climatic Data Center*, www.ncdc.noaa.gov/cag/statewide/time-series/10/pcp/6/08/1895-2014?base_prd=true&firstbaseyear=1895&lastbaseyear=1966&trend=true&trend_base=10&firsttrendyear=1967&lasttrendyear=2014.

[16] “The 1910 Fires.” *Forest History Society*, 9 Oct. 2020, foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/famous-fires/the-1910-fires/.

[17] “The Great Fire of 1910.” *U.S. Forest Service* , USDA, www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5444731.pdf.

before the next morning.[18] This would go against many who theorized that fires could be a form of fire management in order to deter future wildfires, but forestry leaders worked in opposition to discredit such arguments.[22]

In 1942 the U.S. War Advertising Council was concerned that a fire outside the Los Padres National Forest could deter the war effort.[22] In collaboration with the U.S. Forest Service, a campaign was launched to raise public awareness of forest fire mitigation, with Disney temporarily loaning the use of Bambi, who had just made a debut that year, as a mascot.[19] On seeing the popularity of a cartoon persona, the War Advertising Council commissioned Smokey the bear with his first appearance in 1944. The mascot became a popularized icon, turning him into an effective spokesperson for the U.S. Forest Service's mission on reducing and suppressing wildfires.[20] During the two decades post-campaigning, the average number of annual wildfires decreased by 40,000.[22]

Within modern times, uncontrollable wildfires prove that the Blowup and Smokey the bear's impact has done more harm than good for wildlands and communities within the western region. As all fires were seen as problems instead of solutions, forests within the U.S. were able to grow unmanaged. This crowded modern forest yields the fuel for future wildfires to occur.[22] The long-term effects of fire policies within the 1900's West were overlooked by the U.S. Forest Service and have resulted in extremely combustible modern-day forests.

Climate History

Average annual temperature within the U.S. is steadily rising, resulting in a lengthened fire season.

Higher Temperatures

As shown in Figure 1, 2021 is already showing signs of being yet another warm year. Longer summers and shorter winters are becoming a new national trend within the century. As temperatures rise, the cycle of the 4 seasons has started to become relatively unbalanced. As

---

[18] "U.S. Forest Service Fire Suppression." *Forest History Society*, 9 Apr. 2020, foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/u-s-forest-service-fire-suppression/#:~:text=In%201935%2C%20the%20Forest%20Service,day%20following%20its%20initial%20report.&text=With%20such%20tools%2C%20fires%20could,obsessed%20with%20controlling%20large%20fires.

[19] "The Story of Smokey Bear: US Forest Service." *The Story of Smokey Bear | US Forest Service*, www.fs.usda.gov/features/story-smokey-bear#:~:text=Disney%20loaned%20Bambi%20to%20the,Forest%20Service%20artist%20Rudy%20Wendelin.

[20] Joyce, Christopher. "How The Smokey Bear Effect Led To Raging Wildfires." *NPR*, NPR, 23 Aug. 2012, www.npr.org/2012/08/23/159373691/how-the-smokey-bear-effect-led-to-raging-wildfires.

temperatures continue to rise in winter, snow that falls at higher is more likely to fall as rain, and less likely to stick around into spring. With less snow, the majority of forest vegetation and soil are unable to survive modern winters. Snow enacts as a blanket to insulate inches below itself, providing a cover for the ground during winter freezes. As winters become warmer and short lived, the soil becomes exposed to the cold due to less snow on top, resulting in a freeze that damages the roots of trees. Dead trees that die within the winter are able to dry out later in spring and summer, resulting in highly flammable fuel for future wildfires to occur.

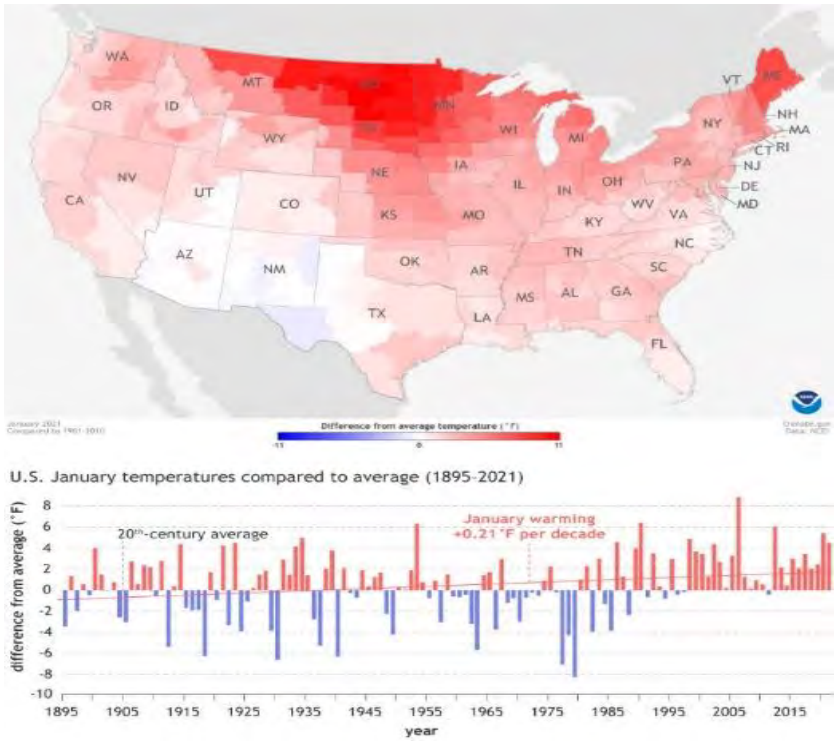


Figure 1, U.S.'s January 2021 temperature comparison. https://www.climate.gov/sites/default/files/US_Jan2021tempanom_graph_1000.jpg

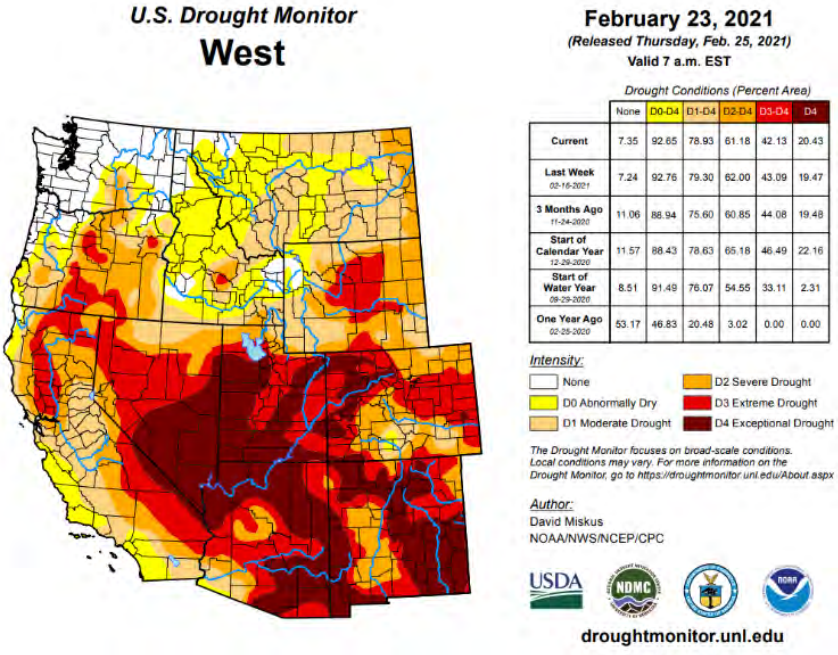


Figure 2, *Map of western region's drought https://www.ncdc.noaa.gov/cag/national/rankings/110/tavg/202101*

With less snowpack developing within the western region's mountains, a continuous pattern of water evaporating over the course of years and more frequent, prolonged droughts has occurred. Just 2 years ago, California officially ended its longest drought consisting of 376 weeks, lasting till 2011 and ending in 2019.[21] Though drought conditions have improved within parts of California, much of the state is still affected as snowfall has still been below average. This continuous dry intensity is noted to contribute to a prolonged wildfire season within western states as dry winds are able to spread fires.

Wildfire Seasons

Wildfire seasons follow the annual cycle of temperatures within specific regions in the U.S. when temperatures are warmest usually during July through August.[22] The western region experiences a summer dryness with major annual precipitation in fall through early spring, having peak wildfire season during the driest segment of their climatological cycle. Typically, California's peak fire season consisted of August through September. Though with longer summers and prolonged drought conditions, California has experienced continued wildfire seasons extending into December.[23] With the growing trend of higher temperatures throughout the years, the typical four-month fire season within the western region has seen an average elongation of 2 months.[24] The prolonging of the western region's wildfire season means future fires will more likely be able to spread out of control in the future.

Infested Trees

Trees are not only impacted by drought conditions due to climate change, but also the growing population of MPB.

Mountain Pine Beetle

With an increase in warmer climates over the U.S.'s climatological cycle, arrivals of drought and shorter winters have stressed out trees. Already dealing with climate change within

---

[21] "California." *Drought.gov*, www.drought.gov/states/california.

[22] Westerling, A. L., A. Gershunov, T. J. Brown, D. R. Cayan, and M. D. Dettinger. " Climate and Wildfire in the Western United States". Bulletin of the American Meteorological Society 84.5 (2003): 595-604. < https://doi.org/10.1175/BAMS-84-5-595>. Web. 26 Feb. 2021.

[23] "When Is California Fire Season? Everything You Need to Know." *Frontline*, 23 July 2020, www.frontlinewildfire.com/when-california-fire-season/.

[24] *Geographic Area Coordination Center (GACC) Website Template*, www.nifc.gov/nicc/predictive/outlooks/outlooks.htm.

the environments, tree populations along the western region are also stressed with a growing population of pests.

Escalating climate change and forest fires are attributing to an outbreak of the Mountain Pine Beetle (MPB), *Dendroctonus Ponderosae*, throughout the western region of North America.[25] The activities of this native species have rapidly increased over the past decade. MPB attacks are common among trees left vulnerable from external factors such as drought, crowning, fire and fungi. Having a one-year life cycle, adult MPB burrow into the bark of large diameter living trees.[23] While burrowed within a host tree, female MPB lay eggs during the late summer, producing the offspring of around 80 eggs.[23] The larvae remain underneath till summer, when they create a network of feeding tunnels. At this point, the tree is under heavy stress and tries to deter the infestation by usage of pitch, driving the beetles out. This weakens its immune system and further stresses out the tree. In typical outbreaks, the host will die and create vast zombie forests consisting of dead standing trees.

Damages

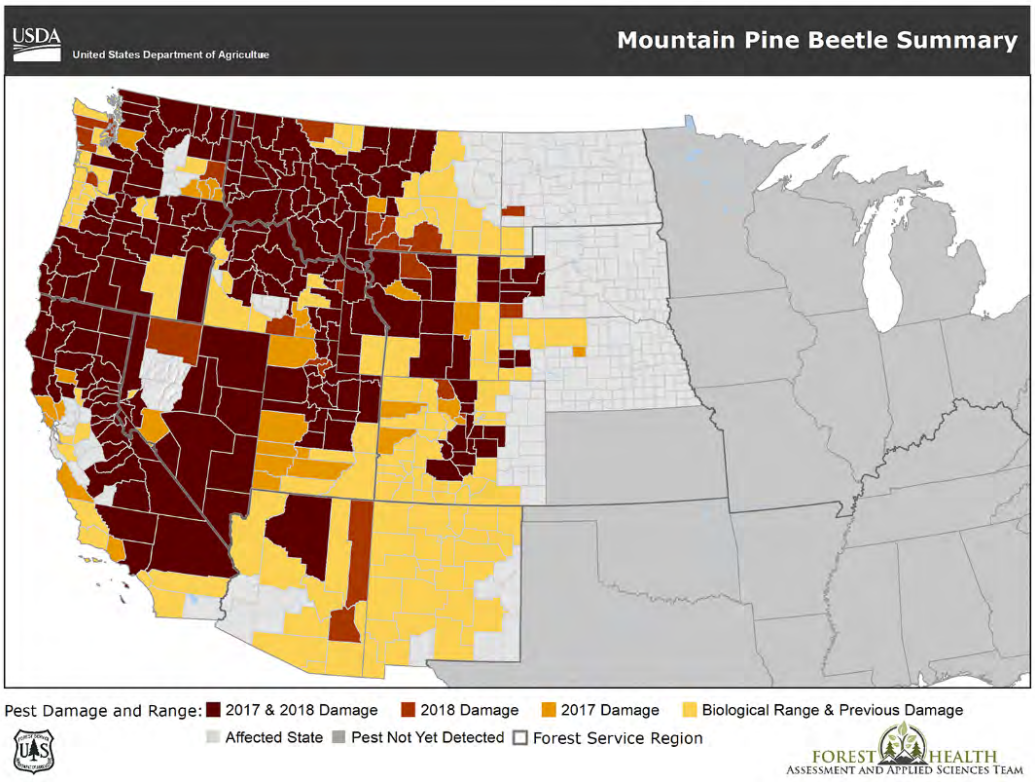


Figure 4, Map of MPB damages over the western region https://www.fs.fed.us/foresthealth/docs/Range_Maps/FDAR-Mountain-Pine-Beetle-Summary-2019.png

---

[25] Leatherman, D. A., et al. "Mountain Pine Beetle." *NEBRASKA INVASIVE SPECIES PROGRAM*, University of Nebraska-Lincoln, neinvasives.com/.

Over the past 20 years, MPB have killed roughly 100 million acres of trees within just the western half of the U.S..[26] With warmer seasons becoming frequent with climate change, MPB are noted to be able to double their population in a drought-stricken year.[27] As such, steady rise in temperatures will further stress native tree populations. Trees unable to produce pitch due to poor hydration will succumb to beetle infestations even faster, and produce more zombie forests.

Forests with large numbers of dead trees are at a significantly higher risk of surface fires ignition, as moisture content within infected trees are much less when compared to healthier fallen trees fallen on the ground.[28] Also trees infested with bark beetle species were chemically altered post infestation. Beetle attacks increase the emission rates of certain terpenes, aromatic compounds found in many plants that naturally occur and are a combination of carbon and hydrogen. The increased potential of a crown fire within beetle afflicted forests can drastically contribute to the spread of wildfires if closely ignited or even carried on by a dry wind. Infested forests pose a liability to communities as wildfires become more frequent within the coming years.

Conclusions

Wildfire potential is a threat to the U.S. if the continued trend of climate uprises in temperature. With snowpacks unable to form properly in comparison to past years, forests are being stressed out due to cold freezes. This results in many trees dying and becoming dry fuel for wildfires to easily spread across the western region's forest. With an increase in temperature though, the fire season within many states can extend even to fall. Trees that have died due to the cold and left unmanaged are now fuel for fires to extend in summer. Resulting in a continuous pattern due to the unbalance within the climatological cycle.

The U.S. is not unfamiliar to fire though. As Native Americans have used fire within their communities to shape the continent before being colonized. Now due to the western approach, fires were vastly seen as just dangerous and should be mitigated at all costs. No fire was a safe fire within the 1900s following policy campaigns that only sought to control fire potential. Unlike then, the U.S. has only now sought fire as a tool to manage forests, yet many forests have

---

[26] Sherylaromero[At]Fs.fed.us. "Forest Health News 2018." *Tree Mortality Summary of WESTERN BARK BEETLES*, www.fs.fed.us/foresthealth/applied-sciences/news/2018/wbb_summary.shtml.

[27] McCollum, Daniel W, and John E Lundquist. "Bark Beetle Infestation of Western US Forests: A Context for Assessing and Evaluating Impacts." *OUP Academic*, Oxford University Press, 8 Mar. 2019, academic.oup.com/jof/article/117/2/171/5372303.

[28] "Bark Beetles." *Bark Beetles - US Forest Service Research & Development*, www.fs.fed.us/research/invasive-species/insects/bark-beetle.php.

grown already out of control without proper management. As this massive forest population and climate change has also begun the spread of MPB into the western region. Able to reproduce and spread like never before due to warmer climate, these beetles left unmanaged will result in even more dry fuel left for future fires to occur.

Works Cited

"2021 Opens with a Warm, Dry January for the United States: NOAA Climate.gov." *2021 Opens with a Warm, Dry January for the United States | NOAA Climate.gov*, 9 Feb. 2021, www.climate.gov/news-features/understanding-climate/2021-opens-warm-dry-january-united-states.

Adam.Smith@noaa.gov. "Billion-Dollar Weather and Climate Disasters: Events." National Climatic Data Center, www.ncdc.noaa.gov/billions/events/US/2000-2020.

Arno, Stephen F., and Stephen Allison-Bunnell. *Flames in Our Forest Disaster Or Renewal?* Island Press, 2013.

"Bark Beetles, Tree Chemistry, and Wildfires: Rocky Mountain Research Station." *Bark Beetles, Tree Chemistry, and Wildfires | Rocky Mountain Research Station*, 1 Oct. 1970, www.fs.usda.gov/rmrs/projects/bark-beetles-tree-chemistry-and-wildfires.

"Bark Beetles." *Bark Beetles - US Forest Service Research & Development*, www.fs.fed.us/research/invasive-species/insects/bark-beetle.php.

"Butte County Fire Burns 30 Homes; 9,000 Flee." *Los Angeles Times*, Los Angeles Times, 13 June 2008, www.latimes.com/archives/la-xpm-2008-jun-13-me-fires13-story.html.

"California." *Drought.gov*, www.drought.gov/states/california.

California Department of Forestry and Fire Protection (CAL FIRE). "2018 Incident Archive." Cal Fire Department of Forestry and Fire Protection, www.fire.ca.gov/incidents/2018/.

California Department of Forestry and Fire Protection (CAL FIRE). "2018 Incident Archive." *Cal Fire Department of Forestry and Fire Protection*, www.fire.ca.gov/incidents/2018/#:~:text=The%20Mendocino%20Complex%20Fire%20burned,California's%20single%2Dlargest%20recorded%20wildfire.

Crockett, Joseph L., and A. Leroy Westerling. " Greater Temperature and Precipitation Extremes Intensify Western U.S. Droughts, Wildfire Severity, and Sierra Nevada Tree Mortality". Journal of Climate 31.1 (2018): 341-354. < https://doi.org/10.1175/JCLI-D-17-0254.1>. Web. 26 Feb. 2021.

Davies, Phill. "The Beetle and the Damage Done." *Federal Reserve Bank of Minneapolis*, www.minneapolisfed.org/article/2012/the-beetle-and-the-damage-done.

Drollette, Dan. “Shorter, Warmer Winters, Less Snow. What next? Q&A with Biologist Pamela Templer .” *Bulletin of the Atomic Scientists*, vol. 76, no. 3, 2020. *Taylor & Francis*, Online, www.tandfonline.com/.

“Forced from Paradise: Leaving Home after One of America's Deadliest Wildfires.” *The Washington Post*, WP Company, 23 July 2019, www.washingtonpost.com/graphics/2019/national/paradise-fire-displaced-residents/.

Gabbert, Author Bill. “August Complex Archives.” *Wildfire Today*, 8 Dec. 2020, wildfiretoday.com/tag/august-complex/.

Geographic Area Coordination Center (GACC) Website Template, www.nifc.gov/nicc/predictive/outlooks/outlooks.htm.

InciWeb developed and maintained by USDA Forest Service, Fire and Aviation Management. “August Complex.” *August Complex Information - InciWeb the Incident Information System*, inciweb.nwcg.gov/incident/6983/.

Joyce, Christopher. “How The Smokey Bear Effect Led To Raging Wildfires.” *NPR*, NPR, 23 Aug. 2012, www.npr.org/2012/08/23/159373691/how-the-smokey-bear-effect-led-to-raging-wildfires.

Leatherman, D. A., et al. “Mountain Pine Beetle.” *NEBRASKA INVASIVE SPECIES PROGRAM*, University of Nebraska-Lincoln, neinvasives.com/.

“Longer Summers.” *Climate Central*, 27 Nov. 2018, medialibrary.climatecentral.org/resources/longer-summers-2017.

NCEI.Monitoring.info@noaa.gov. “Climate at a Glance.” *National Climatic Data Center*, www.ncdc.noaa.gov/cag/statewide/time-series/10/pcp/6/08/1895-2014?base_prd=true&firstbaseyear=1895&lastbaseyear=1966&trend=true&trend_base=10&firsttrendyear=1967&lasttrendyear=2014.

“Newsletter: How the Camp Fire Reshaped a Town Where Nothing Burned.” *Los Angeles Times*, Los Angeles Times, 8 Nov. 2019, www.latimes.com/california/story/2019-11-08/camp-fire-chico-california-newsletter.

Pyne, Stephen J. *Tending Fire: Coping with America's Wildland Fires*. Island Press for Shearwater Books, 2004.

Raish, Carol, et al. “The Importance of Traditional Fire Use and Management Practices for Contemporary Land Managers in the American Southwest.” *Environmental Hazards. 6(2): 115-122*, 1 Jan. 1970, www.fs.usda.gov/treesearch/pubs/23871.

Roos, Christopher I., et al. “Indigenous Impacts on North American Great Plains Fire Regimes of the Past Millennium.” *PNAS*, National Academy of Sciences, 7 Aug. 2018, www.pnas.org/content/115/32/8143.

Saunders, Stephen, and Maureen Maxwell. Clear the Air, 2005, *LeSnow, Less Water: Climate Disruption in the West Less Snow, Less Water: Climate Disruption in the West*.

Sherylaromero[At]Fs.fed.us. “Forest Health News 2018.” *Tree Mortality Summary of WESTERN BARK BEETLES*, www.fs.fed.us/foresthealth/applied-sciences/news/2018/wbb_summary.shtml.

“The Great Fire of 1910.” *U.S. Forest Service* , USDA, www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5444731.pdf.

“The Story of Smokey Bear: US Forest Service.” *The Story of Smokey Bear | US Forest Service*, www.fs.usda.gov/features/story-smokey-bear#:~:text=Disney%20loaned%20Bambi%20to%20the,Forest%20Service%20artist%20Rudy%20Wendelin.

“The 1910 Fires.” *Forest History Society*, 9 Oct. 2020, foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/famous-fires/the-1910-fires/.

“U.S. Forest Service Fire Suppression.” *Forest History Society*, 9 Apr. 2020, foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/u-s-forest-service-fire-suppression/#:~:text=In%201935%2C%20the%20Forest%20Service,day%20following%20its%20initial%20report.&text=With%20such%20tools%2C%20fires%20could,obsessed%20with%20controlling%20large%20fires.

Westerling, A. L., A. Gershunov, T. J. Brown, D. R. Cayan, and M. D. Dettinger. " Climate and Wildfire in the Western United States". Bulletin of the American Meteorological Society 84.5 (2003): 595-604. < https://doi.org/10.1175/BAMS-84-5-595>. Web. 26 Feb. 2021.

“When Is California Fire Season? Everything You Need to Know.” *Frontline*, 23 July 2020, www.frontlinewildfire.com/when-california-fire-season/.

Wildfire Smoke Health Concerns and Movement

Jason Hurwitz

Introduction

As wildfires in the western region continue to increase at a dramatic rate, the smoke they generate has come to represent a growing hazard for the health of the public. Wildfire smoke has the capacity to both invade nearby population centers with a significant density of toxic air pollution and to travel great lengths away from the original fire site, creating a cause for concern to people of all demographics. Of major concern are the high levels of particulate matter with an aerodynamic diameter of 2.5 micrometers (PM2.5), whose health impacts are known to include respiratory and circulatory damage, heart problems, and stroke. In addition, wildfire smoke consists of hundreds of chemicals and gases, many of which have not been studied or are not regularly recorded. With much uncertainty around the concentrations of a wildfire smoke plume, it's necessary to understand the movement of smoke plumes and the adverse effects it has on all living beings and the environment.

Wildfire smoke is known to contain chemicals from Formaldehyde to Benzene and inhaling these in large amounts, especially for extended periods of time, is very dangerous. It's necessary to evaluate each possible chemical to determine both the short-term and long-term effects on health, and to find out who is most vulnerable. Animals are largely at risk from wildfire smoke since their bodies are often not adapted to air pollution, especially marine mammals. Exploring the ways both humans and animals are impacted by wildfire smoke is essential in understanding the health threat posed by plumes of smoke.

Wildfire Smoke Composition

Wildfires smoke contains over 500 chemicals with potentially severe health impacts.

Origin of Particles and Gases

Wildfire smoke is made of hundreds of chemicals and pollutants that have a negative impact on the health of the population and environment. These chemicals come directly from the wildfire's path and are emitted when fuels undergo combustion[29]. The composition of chemicals and gases emitted from wildfires depends on temperature, fuel type, and conditions of combustion. Since this can seem ambiguous because there are hundreds of items within a

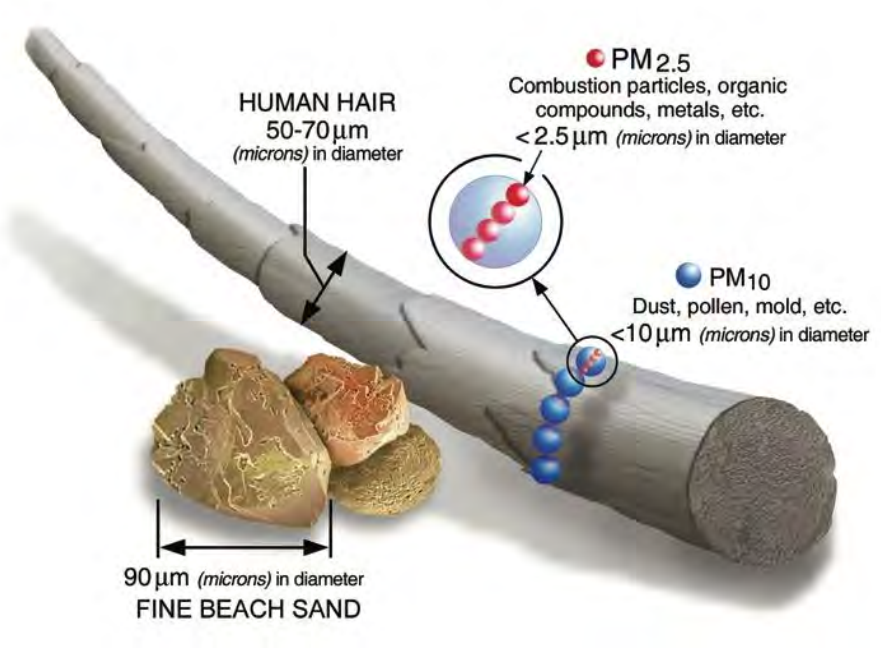
---

[29] See Sokolik and others, Progress and challenges in quantifying wildfire smoke emissions, their properties, transport, and atmospheric impacts

household that could be impacted by a wildfire, it is essential to understand the risks involved from the vast array of chemicals likely to be in the smoke.

The concentration of wildfire smoke depends on several important factors. If there are high temperatures, dry fuels, and complete combustion, there would likely be an increase in a multitude of emissions including: carbon dioxide (CO_2), ash, water vapor, nitrogen oxides (NO_x), and sulfur dioxides (SO_2). Nonetheless, when hazardous emissions such as carbon monoxide (CO), hydrogen sulfide (H_2S), hydrogen cyanide (HCN), and ammonia (NH_3) are released, it is caused by partial oxidation of fuels. These are very dangerous chemicals and can have dramatic impacts on the health of those residing in the path of the smoke.

Furthermore, the particles emitted directly from wildfires play a multidimensional role in the environment and the future of climate change as they linger in the atmosphere. Large wildfires usually burn as a result of continuous high-pressure systems, driving minimal precipitation and dry fuels. Smoke particles that are larger in size tend to be deposited within 1-2km of the wildfire. However, smaller particles become injected high in the atmosphere and can stay there for months. It can even reach the lower stratosphere, influencing the effects of climate change. These types of aerosols being concentrated in the lower stratosphere from extreme wildfires in western North America have been compared to a moderate volcanic eruption. An entire season of extreme wildfires could significantly perturb the stratosphere and put not only the health of the environment in danger but the population as well.



Dangers of Small Particles

Beyond worsening the state of the stratosphere, wildfire smoke is known to contain dangerous elements that are harmful for humans. Particulate matter is a very small particle (see Figure 1*)* that is released from the burning of wildfires and from urban activities such as use of a vehicle. These particles are smaller than the sand found on the beach and can easily enter the body during smoky conditions. In relation to the air pollution in the U.S.,

the current levels of PM from wildfire smoke is 40% in the U.S.[30] Wildfire smoke exposure is a growing risk largely due to the concentrations of PM and the dangers associated with inhaling it.

While the manner in which particulate matter becomes a serious threat to health is unclear, there is evidence that chemical composition, particle size, number, and shape are all factors of importance.[31] Research has been stunted due to the lack of knowledge of differences between air pollutants in an urban setting and those from wildfires, and whether the already studied adverse health impacts from the urban setting are generalizable to wildfire smoke. Nonetheless, the research conducted thus far has provided insight into specific areas of knowledge.

Particulate matter is very dangerous for the respiratory system and could have long-term negative health impacts. It causes adverse effects in pulmonary oxidative stress and inflammation. Particulate matter, especially $PM_{2.5}$ is small enough to penetrate into the bloodstream by the movement of pro-inflammatory, pro-coagulation, and pro-oxidant components of PM into the circulation.[32] This can occur through pulmonary changes induced by PM or through changes in the autonomic nervous system that are PM-mediated changes. Oxidative stress can lead to DNA damage and is dangerous for the human body.

In Vivo mice studies have shown significant associations between PM exposure and adverse health effects. Mice exposed to PM have exhibited increased oxidative stress, cell death, lower counts of lung macrophages, and higher levels of inflammatory cells and cytokines. This study was from a California wildfire and while it was a study on mice, *in vivo* human studies have produced similar results. In these studies, humans exhibited increased inflammatory responses, elevated cytokines, and elevated band neutrophil counts in peripheral blood. These can impact the cardiovascular system in many ways, all of which being negative.

Nitrogen Oxides

Another dangerous gas that travels downwind from the wildfire site is nitrogen oxide (NO_x). This group of gases is highly reactive and goes through many chemical reactions in the wildfire smoke plume. Wildfires are one of the largest producers of this gas, making up about 15% of the total NO_x budget.[33] In high concentrations, NO_x has negative effects on human health and is associated with the inflammation of lungs. Severe toxicity can occur only after one or two deep inhales, demonstrating just how dangerous and potent this gas is.

---

[30] See the Environmental Protection Agency's', The Danger of Wildfire Smoke to Public Health

[31] See Liu and others, A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke

[32] See Sokolik and others, Progress and challenges in quantifying wildfire smoke emissions, their properties, transport, and atmospheric impacts

[33] See Anna Mebusts, Variability in wildfire emissions of nitrogen oxides as observed from space

Nitrogen oxide isn't only negatively impacting humans, but it is also threatening the ecosystems in the smoke plumes' path. This gas accelerates global warming by trapping heat in the atmosphere and warming the planet. This perpetuates losses in biodiversity, disrupting the balance of ecosystems around the world. In the western region of the U.S., the increase in wildfire smoke will likely follow this trend and continue to aggravate the species living within the region.

Volatile Organic Compounds

A group of compounds known as Volatile Organic Compounds (VOC's) are known to be concentrated within wildfire smoke. These compounds are very harmful for humans and can cause symptoms ranging from liver damage to cancer[34]. The capacity to which it adversely affects humans is based on the concentration of it in the atmosphere and the length of exposure to these chemicals. VOC's include chemicals such as Benzene and Formaldehyde which illustrates just how vast the types of chemicals make up the smoke plumes. In fact, there are over 200 different organic species considered to be VOC's often concentrated in wildfire smoke, with most of them being rarely measured and reported. VOC's also play an important role in the creation of ozone by reacting with NO_x to create ozone molecules.

Ozone

Frequently, wildfire smoke has the necessary conditions to participate in local ozone production which can be harmful in many ways. Wildfires have the ability to generate both the nitrogen oxide species and the volatile organic compounds that are necessary for ozone production. Nonetheless, the relative abundance of each compound depends on the source of fuel as well as various other burn conditions.[35] With these factors in mind, the generation of ozone downwind of a fire is often common. Similar in the ways PM can be transported far away from the original wildfire, ozone has the potential to travel long distances.

One way spikes in ozone production occur downwind from a fire site can occur is through the mixture of anthropogenic air pollution in combination with the wildfire smoke. However, ozone levels are not commonly reported in studies looking at wildfire smoke and human health outcomes as most of the worry is around PM. Nonetheless, spikes in ozone can be detrimental for human health, causing damage to the lungs and other respiratory diseases. With the combination of anthropogenic air pollution and wildfire smoke, there is serious worry for the health of the population. It is reasonable for this worry to increase as ozone will continue to accumulate over time.

---

[34] See British Columbia's, Indoor Air Quality: Volatile Organic Compounds (VOCs)

[35] See Carolyn Black and others, Wildfire Smoke Exposure and Human Health: Significant Gaps in Research for a Growing Public Health Issue

Ambiguity of Chemicals and Interactions

With a combination of over 500 chemicals and gases, wildfire smoke exposure threatens the health of humans. These chemicals are oftentimes not recorded which means there are even more dangers associated with smoke exposure that remain unknown. As wildfires occur with greater intensity and frequency, it is more likely for a wider variety of materials to be consumed by the fire itself, causing an ambiguous mixture of chemicals and gases. Further research is necessary to fully understand what comprises the concentration of wildfire smoke, and to discover the intricate compounds hidden within plumes.

Smoldering vs. Flaming Conditions

Emissions produced from wildfire smoke vary greatly depending on the combustion condition. There are two main phases that describe these conditions and change the composition of the chemicals emitted: smoldering and flaming. It is important to understand the ratio of the fire between these two conditions as flaming emissions are more efficient, resulting in a distinctive form of smoke.[36]

Smoldering conditions feature a great amount of smoke with reduced flames. If the wildfire is smoldering, there will be greater levels of Volatile Organic Compounds, NH_3, and primary PM. With higher concentrations of $PM_{2.5}$ and PM_{10} in the atmosphere, it causes greater concern for the safety of people in the path of smoke. However, this condition produces less black carbon and less NO_x. This type of condition is likely to be safer for the environment in comparison with flaming conditions since black carbon has negative effects where it makes landfall. Nonetheless, smoldering will last longer which can have more detrimental impacts on the health of the population and the environment.

The other combustion condition of concern is flaming. This is described as a more noticeable burn since there are greater black carbon levels polluting the air. In addition, the wildfire smoke consists of lower rates of VOC's, NH_3, and primary PM. Nonetheless, the flaming condition also has more NO_x. This condition is safer for humans but could have detrimental impacts on the environment.

Wildfire Smoke Movement

Smoke plumes can cover large areas and extend over continents.

---

[36] See Sokolik and others, Progress and challenges in quantifying wildfire smoke emissions, their properties, transport, and atmospheric impacts

Factors of Downwind Movement

Wildfire smoke is incredibly dangerous and its movements towards adjacent and downwind communities adds to the level of urgency. The smoke can be up to four times more dangerous than where it was initially burnt as it undergoes more chemical reactions and hovers over certain regions. These smoke plumes can be transported over vast distances. In recent years, wildfire smoke originating in the western region of the United States has traveled as far as Europe.

While most smoke will stay in the lower levels of the atmosphere, there is a small amount of brown carbon released into the upper atmosphere. This can have major impacts on warming and cooling of air on earth as the brown carbon particles interfere with rays from the sun. This has an unusually large effect on the planetary radiation balance. In addition, brown carbon is created from incomplete combustion when grasses, wood, and other biological matter smolders. Black carbon rarely reaches these levels of the upper troposphere but both brown and black carbon particles interfere with solar radiation by absorbing and dispersing the sun's rays.[37]

Once brown carbon is transported by smoke in the lower atmosphere, it eventually mixes with clouds. These clouds carry the brown carbon in an upward convection flow that travels to the upper troposphere. There is still not enough research to provide clarity into the ways the rest of the smoke plumes travel, but recent studies help provide some insight.

Wildfire smoke plumes tend to circumnavigate the earth and are removed through natural processes such as impaction scavenging where aerosol particles collide with hydrometeors, becoming either dissolver, attached or embedded[38]. Another factor that dramatically removes smoke plumes from the atmosphere is precipitation. If there is no precipitation, the smoke plumes are likely to lead a longer atmospheric lifetime and long-range transport.

Toxicity

Wildfire smoke exposure is estimated to be the cause of over 339,000 premature deaths a year around the world, much higher than that of those directly from the wildfire. Moreover, as wildfire smoke ages, there are a multitude of chemical reactions taking place that make it more toxic. The smoke particles undergo oxidation, converting the compounds in the smoke plume into "highly reactive compounds."[39] With that said, smoke plumes can become up to four times more toxic as they age providing concern for those in areas where the smoke could travel towards. Smoke particles also contain carcinogens which will also oxidize as the smoke ages, becoming even more carcinogenic and increasing the risk of cancers. This is a major concern for

---

[37] See Brown and Atkinson's, Smoke from Wildfires Can Have Lasting Climate Impact—Climate Change: Vital Signs of the Planet

[38] See Sokolik and others, Progress and challenges in quantifying wildfire smoke emissions, their properties, transport, and atmospheric impacts

[39] See Gray's, Four Time More Toxic: How Wildfire Smoke Ages over Time

the global population due to the expansive nature of wildfire smoke and the relative immobility of communities.

Future Pathway

One way to determine the distance and the direction the smoke will travel in is the smoke injection height. Since plumes are often formed from wildfire smoke, these plumes inject the smoke thousands of feet above the earth and into the stratosphere. When smoke is blocked or trapped from the weather conditions, or the smoke does not reach a certain altitude, it is considered to be a local or regional problem in the sense of severity of health outcomes. However, when the smoke becomes lifted high and hits elevations as high as the stratosphere, it can move over oceans and continents.[40] Smoke plumes can grow rather large and the typical smoke plume core is approximately 100m.[41]

In regions where there are valley formations and a complex terrain such as the western region of the U.S., the concentrations of wildfire smoke can vary. Winds known as drainage winds often pull the smoke into the valleys at night and this air gets trapped and cooled. Eventually, when the sunlight hits the valley floor, the clouds are able to rise back up at a higher elevation. This is just another dimension that plays a role in the pathway of wildfire smoke. In the figure to the right (see Figure 2*)*, the visibility of the smoke plumes is clear from this satellite image. When assessing this picture, the window is blowing west, taking the wildfire smoke away from the North American continent and into the Pacific Ocean. As previously discussed, this smoke is largely influenced by the meteorological conditions. If the wind were to change direction and blow East, this smoke plume would come back to land and would continue to cover the U.S.. This has happened in previous large fires in the western region where there was no clear wind pattern, and the smoke concentrated in indefinite ways.

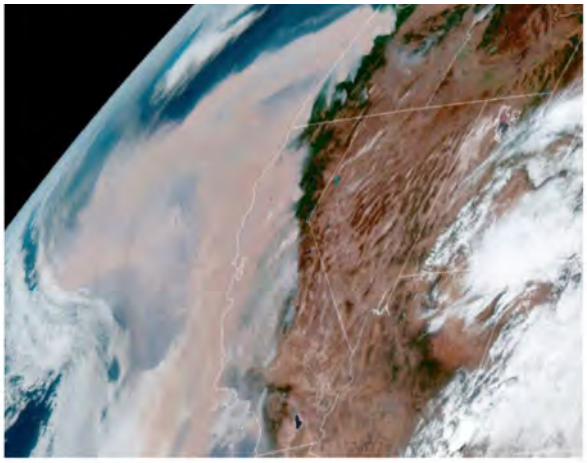


Figure 2: Wildland fire smoke plumes from the Western region blowing with the wind away from the United States and into the Pacific Ocean. (www.phl17.com/web-exclusives/smoke-cyclone-airborne-

To demonstrate this even further, an example of multiple large movements in the atmosphere that impacted the direction the wildfire smoke blew was during the western regions' drastic wildfires in September 2020. During this time, the wildfire smoke was blowing towards the east. However, there were two hurricanes simultaneously raging in the East, one in the

---

[40] See Grable's, Wildfire smoke travels far but never really disappears

[41] See Kahn and others, Wildfire smoke injection heights: Two perspectives from space

Southern region and one in the North. These hurricanes blocked the smoke plumes from traveling further into the Atlantic and Hurricane Sally in the Southeast was strong enough to blow the plume North. As provided in the figure below (Figure 3*),* once Hurricane Paulene in the Northeast dies down, Hurricane Sally is able to push the direction of the smoke in the Northeast and the Atlantic Ocean. At the bottom of the picture, there is a scale that shows the amount of black carbon in the smoke plume by mass density. This black carbon provides a fair amount of health concerns and demonstrates further how everyone in the United States, and especially those in the West need to take precautions for their health when wildfires become far-reaching and the smoke emitted all-encompassing.

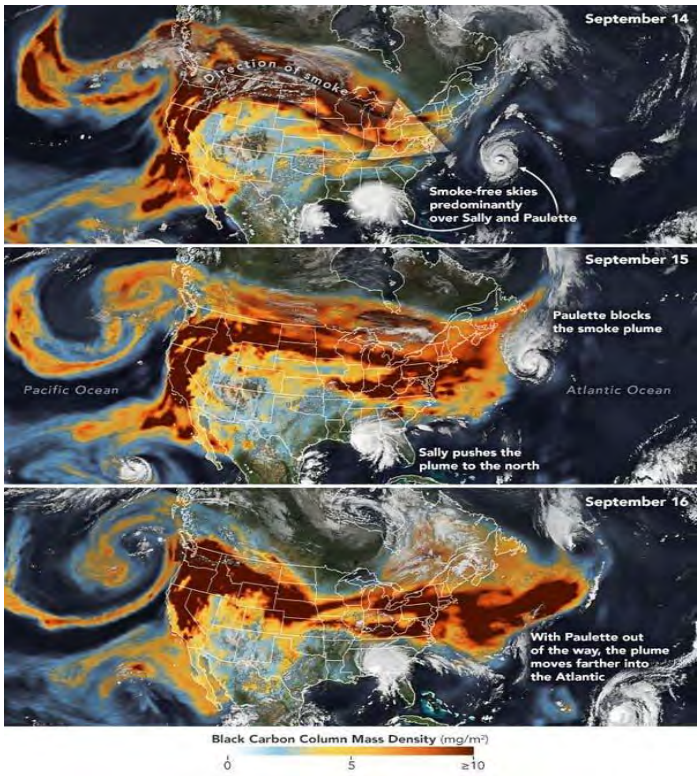


Figure 3: Multiple extreme weather events in the United States pushing a very large wildland fire smoke plume around the country. (www.phys.org/news/2020-12-wildfire-ages-downwind-air-quality.html)

Specific Health Concerns

Wildfire smoke contains a multitude of dangerous chemicals and these have adverse effects on human health.

Illnesses associated with Wildfire Smoke

Wildfire smoke is extremely dangerous to inhale due to the vast number of particles. Specifically, the size and chemical composition of airborne particles affects its impact on human health. The particles that are smaller have the worst effects. Given their small size, these particles

are capable of depositing themselves deep in the respiratory tract[42]. In addition, these particles have been associated with all-cause mortality which was measured in one study by determining the visibility and concentration of PM_{10} in the atmosphere[43]. It was found that smoke exposure was responsible for about 29% of the 10,859 excess deaths during a 44-day heat wave in Moscow. Similar findings have been determined in Australia, Madrid, and Brazil. Moreover, in southern Europe, one study found increases in cardiovascular mortality that was associated with PM_{10}. It was determined that fires burning over 3000 hectares were considered large fires and these had a much larger association with mortality than smaller fires. In addition to this, there was an association found between temperature and PM_{10} from wildfires. At times of high heat, there were greater levels of PM_{10} released, contributing to over 2000 deaths in one study.[44]

The lungs are significantly vulnerable to prolonged smoke exposure. Cases have found associations between exposure of wildfire smoke and major declines in lung function in children without asthma. In adults with asthma, wildfire smoke exposure exacerbates the symptoms of asthma.[45] During a wildfire in Southern California, people with asthma reported higher levels of rescue medication usage. In children, those with asthma don't seem to be impacted by exposure but in those without asthma, studies show decreased lung function. In those with Chronic Obstructive Pulmonary Disease (COPD), epidemiological evidence has shown associations between wildfire smoke exposure and worsening symptoms of COPD. This correlation was found by measuring the usage of reliever medication which significantly increased during episodes of exposure to wildfire smoke.

In British Columbia, over the course of ten fire seasons, an association was found between wildfire smoke exposure and ED visits for pneumonia and acute bronchitis. In relation to these two specific illnesses, the effects of wildfire smoke exposure and urban air pollution are very similar in terms of respiratory outcomes. In addition, the combination of these two can make inhalation much more dangerous. In places where there was bushfire smoke, the risks can be greater for these illnesses.

Cardiovascular outcomes from wildfire smoke exposure are mixed but still significant. In Australia, rates of out-of-hospital cardiac arrests were associated with $PM_{2.5}$ from wildfires. Similar to this, hospitalizations for acute myocardial infarctions were also associated with $PM_{2.5}$ from wildfire smoke exposure. In North Carolina, ED visits for congestive heart failure were associated with wildfire smoke exposure. Moreover, it was found that an increase of 100 $\mu g/m^3$ in wildfire smoke related $PM_{2.5}$ was associated with a 42% increase in congestive heart failure

---

[42] See Liu and others, A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke

[43] See Reid's and others, Critical Review of Health Impacts of Wildfire Smoke Exposure

[44] See Liu and others, A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke

[45] See Reid's and others, Critical Review of Health Impacts of Wildfire Smoke Exposure

emergency room visits (CHF)[46]. However, in Southern California, there was only a suggestive association for congestive heart failure hospitalization and $PM_{2.5}$ from wildfire smoke plumes[47].

Another negative outcome from wildfire smoke exposure is an impact on birth outcomes. There is already literature existing on the association between exposure to air pollution and adverse birth outcomes. Wildfire smoke exposure adds even greater levels of pollution into the air, increasing the changes of negative birth outcomes. In fact, during the 2003 southern California wildfires, babies that gestated during this period were found to have lower birth weights overall compared to those born in the region nine months prior. In Indonesia, "the most important predictor of 'missing' children from the Indonesian 2000 Census" was prenatal smoke exposure during the third trimester of pregnancy. More convincing evidence of this was recorded in Brazil where women exposed to high levels of $PM_{2.5}$ from wildfire smoke had higher rates of low birthweight babies. This can have very negative consequences for the child and may lead to fatality in certain cases.[48]

In comparing the effects of wildfire produced PM versus anthropogenic PM, the human bronchial epithelial cells experience increased inflammation from wildfire derived PM. Moreover, this exposure showed declines in glutathione, an important antioxidant for the human body as well as increased cell death in human lung epithelial cells. This might provide greater insight into the differences in these types of PM, and how further research is necessary to understand the specific risks associated with the inhalation of each.

Other associated illnesses included diarrhea from power outages after wildfire events and blood biomarkers for inflammation and bone marrow content. Moreover, there were significant associations between wildfires and adverse symptoms with systemic inflammation, bone marrow content, physical strength, and overall health.[49] In more rare events, bacteria and fungi can be transported in the wildfire smoke plumes. These microbes are often active agents that are spreading infection. One type of airborne fungus called coccidioidomycosis that becomes airborne when soils are disturbed is the cause of a very serious infection called Valley fever.[50] It is not determined which microbes are carried in smoke and how far they can travel, but there have been cases of microbes being carried by wildfire smoke making people ill. In addition to these more severe illnesses, there are also a multitude of common symptoms from wildfire smoke exposure. The most common of these include "eye and throat irritation, shortness of

---

[46] See Liu and others, A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke

[47] See Reid's and others, Critical Review of Health Impacts of Wildfire Smoke Exposure

[48] See Reid's and others, Critical Review of Health Impacts of Wildfire Smoke Exposure

[49] See Liu and others, A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke

[50] See UC Davis's, Wildfire smoke can carry microbes that cause infectious diseases

breath, headaches, dizziness, and nausea."[51] These symptoms are likely to be enhanced when PM concentration is elevated, even for healthy individuals.

Most at Risk

Measures for determining those most at risk involved factors such as age, gender, pre-existing diseases, socioeconomic status, and ethnicity. These conditions all play a role in the resources available to communities and those most vulnerable. One group significantly at risk is children without asthma. Studies have shown that short-term inhalation of wildfire smoke can compromise lung immune responses leading to lung infections. Children with asthma seem to not be as impacted as one would expect, and symptoms may be only slightly exacerbated. Moreover, asthma hospitalizations for those between 0-5 years old were greatly associated with $PM_{2.5}$ exposure compared to older children and adults less than 65 years old. The findings for differences by age are not conclusive. In Malaysia, a study of PM_{10} exposure from wildfires found higher rates of mortality in those between the ages of 65-74 years old. In addition to this, people over the age of 65 had higher rates of respiratory hospitalizations when compared to younger adults exposed to the wildfire smoke. In California wildfires, older adults had higher rates of hospitalization for asthma than younger aged people. However, there are studies that find a different conclusion.[52] It is likely that the increasing amount of asthma attacks and throat irritation is due to a high concentration of ozone in the atmosphere.[53] This is especially common when those with asthma are exercising during unsafe conditions.

In Indonesia, there were greater adverse effects for younger people rather than older. Respiratory admissions to the hospital exceeded prediction for those aged 40-64 years old, however, not for those aged over 65.[54] Studies in North Carolina found similar results as there were greater ED visits for COPD, pneumonia, and acute bronchitis from those aged younger than 65 years old who had exposure to peat fire smoke. Furthermore, those with pre-existing cardiac or respiratory conditions are likely to be more vulnerable to wildfire smoke exposure, though current research is inconclusive.

While there have only been a few studies researching the impact of socio-economic status (SES) on wildfire smoke exposure, recent studies have provided a stronger lens into the magnitude of the situation. In North Carolina, countries with lower SES had both higher rates for ED visits for asthma and CHF when compared against countries with a greater SES. Similar results were produced in Indonesia where areas with lower food consumption had greater adverse associations with smoke exposure and survival of birth cohorts when compared to those

---

[51] See the U.S. Forest Services, Health Impacts – Forest Service Air Resource Management Program

[52] See Reid's and others, Critical Review of Health Impacts of Wildfire Smoke Exposure

[53] See the U.S. Forest Services, Health Impacts – Forest Service Air Resource Management Program

[54] See Reid's and others, Critical Review of Health Impacts of Wildfire Smoke Exposure

who had larger household food consumption. Similarly, those from a lower SES likely can't afford some of the higher quality air filters and products to help reduce emissions within the household as opposed to those from a higher SES. Those in a lower SES are also more likely to live in an urban area where urban PM might already be at a high. This can exacerbate the symptoms from wildfire smoke since there is a greater concentration of PM in the air. Furthermore, those who are houseless lack access to clean air, making it impossible to avoid and incredibly dangerous to inhale for extended periods of time.[55]

Age plays a multidimensional role in terms of health concerns resulting from exposure to wildfire smoke. It is generally concluded that elders are at highest risk for mortality from smoke exposure, especially if they have any cardiovascular or respiratory issues. Elders with COPD are likely to be the most impacted by the smoke exposure as the increased inflammation of lungs and other organs could be fatal for those with compromised respiratory systems. In addition to this, since the smoke can carry bacteria and fungi, this puts elders at an even higher risk due to the unknown of the concentration of wildfire smoke. In the figure above (see Figure 4*),* an elderly woman is leaving with her animals as the wildfire flames in the background. While the physical fire may be the biggest threat in that moment, the inhalation of PM and other gases within the smoke can detrimentally impact her health in the long-term.

There have been very few studies on the impact of race in terms of wildfire smoke exposure and health impacts. The major study conducted was on Aboriginal Australians who are a minority group and were found to have a higher risk of respiratory admissions and ED visits than other races when exposed to PM_{10} from wildfire smoke. While these results are not generalizable to other minority groups, future research may present similar findings in other countries.[56] Differences in gender showed a slight impact on the potential for adverse health effects from wildfire smoke exposure. The one major finding was that asthma-related symptoms from wildfire smoke were higher for women than men. Nonetheless, there were not any significant differences in gender for wildfire smoke in relation to respiratory and cardiovascular physician visits.

Long-term Inhalation Concerns

Lack of research in terms of long-term health effects from wildfire smoke exposure has resulted in a significant knowledge gap. One particular study that took place in Montana looked at these health effects over the course of a few months where the daily average of $PM_{2.5}$ in the air was 221 micrograms per cubic meter of air. When compared to those in the community that hadn't been exposed to such high levels of smoke, those from the polluted area had poorer lung

---

[55] Cunningham and Temming's, What we know and don't know about wildfire smoke's health risks

[56] See Liu and others, A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke

function only after one to two years after the wildfire. It was noted that it was originally thought that "people might be worse right after" the event of a wildfire, "but it's a little bit of a delayed response."[57] Based on this evidence, long-term health effects are likely to be significant and future studies are needed to provide greater evidence.

Healthcare costs

Wildfire smoke exposure has been associated with increases in physician visits for specific problems such as respiratory illness, increases in emergency department visits, and even increases in hospitalizations. During a 12-week period of exposure to wildfire smoke in California, there were major increases in primary care contacts.[58] With hospital visits increasing, the cost on the healthcare industry is dramatic. In times where viruses are common or a pandemic is occurring, adding the extra layer of wildfire smoke exposure is likely to overstress hospitals and fill them to maximum capacity.

Environmental Impacts

The impacts from wildfire smoke are not only adverse for humans but have lasting impacts on the state of the environment.

Water Pollution

Since the mass amount of chemicals and particles in a smoke plume need to make landfall at some point, oftentimes it lands in a body of water. This can have negative effects on the quantity and quality of water available and can leave the water polluted for years to come. Polluting the water most significantly is ash and other contaminants that eventually settle on streams, lakes, and water reservoirs.[59] Moreover, when ash lands on vegetation, once there is precipitation, the remnants of ash and contaminants flush into streams, rivers, and downstream reservoirs. One common resting spot for smoke from large wildfires in the western region of the United States is in Northern Utah. This has caused major water contamination in this area.

On a recreational level, "naturally occurring and anthropogenic substances can impact water quality, discolor recreational waters, and may potentially contribute to harmful algal blooms."[60] This is often due to an absence of vegetation which drives the likelihood for erosion and flooding. People located in the WUI and near large wildfires are at greatest risk of having contaminated water as the ash is likely to settle near the burn site. Those in the western region of

---

[57] Cunningham and Temming's, What we know and don't know about wildfire smoke's health risks

[58] See Liu and others, A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke

[59] See the Environmental Protection Agency's, Wildfires: How Do They Affect Our Water Supplies?

[60] See Mendenhall's, Wildfire's Impact on Our Environment

the U.S. are at a high risk of contaminated water since 65% of fresh water supply in the region originates from forested watersheds. It is likely that many of these forests will catch fire at some point, leading to high rates of water contamination.[61] Further research has determined that streams in the northwestern United States have a significant increase in the amount of suspended sediments in bodies of water after a wildfire.

Diversity of Ocean Ecosystems Concerns

When wildfire smoke is transported over oceans, there is usually a large withdrawal of smoke and ash which plays a very negative role into marine ecosystems. Much of the charred matter from wildfires kills plants and animals immediately. Fish are a prime victim to this as burnt debris blocks the gills of fish, making them unable to breath and eventually die. It also causes sunlight to not reach its usual depths in the ocean, making many plants and animals that rely on the sun for photosynthesis to die out. An extreme example of this was in 1997 after Indonesia wildfires where the coral reefs in the Indian Ocean were suffocated due to insufficient sunlight. At the core of this ecosystem is seagrass and seaweed. If these plants are degrading, the entire food chain will be affected.[62]

Another issue associated with wildfire smoke depositing particles in the ocean is the risk of algae blooms. Chemicals like phosphorus, nitrogen, and potassium often enter the ocean and create algae bloom that significantly disrupt the marine ecosystem. Algae blooms are often toxic to humans and pets, and by removing oxygen from the water, marine species are being suffocated by the presence of these blooms. Since larger marine mammals such as whales and dolphins are adapted to life at sea with little to no air pollutants, they are likely to be more susceptible to illness and disease from inhaling the chemicals. For already endangered species such as sea otters and orcas, this could lead to a dramatic decline in the species population.[63] A 2014 California study on sea otters found that exposure to wildfire smoke weakened their immune systems. Nonetheless, this was a small study and further research is necessary.

Most at risk for inhaling large amounts of unhealthy chemicals are whales, dolphins, and porpoises. Through their blowholes, they take in big gulps of air rapidly which can bring in large amounts of PM and other dangerous chemicals to their system and cause adverse effects. In addition to this, they are also more vulnerable because they lack sinuses and nasal structures found in land animals. While land animals are able to sneeze and cough out particles, marine species don't have this capability and are therefore more vulnerable to the toxic chemicals plaguing their habitat. The BP oil spill might provide insight into the ways wildfire smoke could

---

[61] See the Environmental Protection Agency's, Wildfires: How Do They Affect Our Water Supplies?

[62] See Osbourne's, Learn 3 Ways Wildfires Are Affecting the Ocean

[63] See Brishti's, Wildfire Smoke May Harm Whales and Dolphins: Here's What We Know

injure marine mammals. There were an amassing 46 dolphins that washed ashore dead during this time. These dolphins had “severe lung disease and degenerated adrenal glands—organs that regulate hormones, the immune system, responses to stress, and more.” Scientists believe this can be generalized towards wildfire smoke exposure as exposure to hydrocarbons from smoke can lead to similar adrenal atrophy and ultimately harm their reproductive systems.

Conclusion

Wildfire smoke is a cause of great concern for the future of the population’s health as well as the environment. It’s essential for the public to be aware of the dangerous chemicals and gases they may be inhaling from the smoke plumes before another strong wildfire season starts. This smoke has been found to cause severe illnesses and increase mortality rates in humans. As it travels downwind, the wildfire smoke can become up to four times more toxic. With that said, populations should be attentive to the growing threat posed by wildfires and the potential health effects its smoke is associated with. Although these effects may vary, there is no doubt that exposure to smoke affects people of all demographics in alarming ways; the extent to which requires further study.

Wildfire smoke exposure also has harmful impacts on the future of the earth and it’s warming process. Since these adverse effects from smoke impact a majority of people and animals, it is necessary to bring further attention to the issue to improve the safety of the environment and the species that inhabit it. It is especially important to bring greater awareness to the realities of those from a low SES and make informed decisions from it. Those with a lower SES lack the necessary resources to help avoid the smoky conditions and for many of these groups, they are more vulnerable to the health hazards created by wildfire smoke.

- Wildfire smoke is a cause of danger to all populations and can be life-threatening for those most vulnerable.
- Wildfire smoke grows more toxic as it travels away from the wildfire site which broadens the pool of those impacted by high toxicity plumes
- Wildfire smoke further disadvantages communities of a lower SES where resources and access to adequate health accommodations are already lacking
- The impact on both land and marine ecosystems is detrimental, and further research is needed in order to understand the lasting impact

Works Cited

Basu, Brishti. “Wildfire Smoke May Harm Whales and Dolphins: Here's What We Know.” National Geographic, 30 Sept. 2020, www.nationalgeographic.com/animals/2020/09/whales-dolphins-harmed-wildfires-smoke-west/#close.

Black, Carolyn, et al. “Wildfire Smoke Exposure and Human Health: Significant Gaps in Research for a Growing Public Health Issue.” Environmental Toxicology and Pharmacology, U.S. National Library of Medicine, Oct. 2017, www.ncbi.nlm.nih.gov/pmc/articles/PMC5628149/.

Brown, Josh, and Joe Atkinson. “Smoke from Wildfires Can Have Lasting Climate Impact – Climate Change: Vital Signs of the Planet.” NASA, NASA, 26 June 2017, climate.nasa.gov/news/2597/smoke-from-wildfires-can-have-lasting-climate-impact/.

Cunningham, Aimee, and Maria Temming. “What We Know and Don't Know about Wildfire Smoke's Health Risks.” Science News, 19 Sept. 2020, www.sciencenews.org/article/wildfire-smoke-health-risks-air-quality-pollution.

Grable, Juliet. Wildfire Smoke Travels Far but Never Really Disappears, www.msn.com/en-us/weather/topstories/wildfire-smoke-travels-far-but-never-really-disappears/ar-BB19MwSA.

Gray, Richard. “'Four Times More Toxic': How Wildfire Smoke Ages over Time.” Horizon, horizon-magazine.eu/article/four-times-more-toxic-how-wildfire-smoke-ages-over-time.html.

“Indoor Air Quality: Volatile Organic Compounds (VOCs).” HealthLink BC, 14 Jan. 2021, www.healthlinkbc.ca/healthlinkbc-files/air-quality-VOCs#:~:text=VOCs%20include%20a%20variety%20of,kidney%2C%20or%20central%20nervous%20system.

Kahn, Ralph A., et al. “Wildfire Smoke Injection Heights: Two Perspectives from Space.” Geophysical Research Letters, vol. 35, no. 4, 2008, doi:10.1029/2007gl032165.

Liu, Jia C, et al. “A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke.” Elsevier, doi.org/10.1016/j.envres.2014.10.015.

Mebust, Anna K, et al. “Variability in wildfire emissions of nitrogen oxides as observed from space.” UC Berkeley, https://digitalassets.lib.berkeley.edu/etd/ucb/text/Mebust_berkeley_0028E_13817.pdf

Mendenhall, Jared. “Wildfire's Impact on Our Environment.” Utah Department of Environmental Quality, 30 Aug. 2019, deq.utah.gov/communication/news/featured/wildfires-impact-on-our-environment.

Osbourne, Lindi. “Learn 3 Ways Wildfires Are Affecting the Ocean.” Swim Guide, 1 Apr. 2020, www.theswimguide.org/2020/02/21/learn-3-ways-wildfires-are-affecting-the-ocean/#:~:text=Wildfire%20smoke%20and%20debris%20may,flows%20across%20the%20burnt%20land.

Reid, Colleen E, et al. Environmental Health Perspectives Main Page, doi.org/10.1289/ehp.1409277.

Sokolik, I. N., Soja, A. J., DeMott, P. J., & Winker, D. (2019). Progress and challenges in quantifying wildfire smoke emissions, their properties, transport, and atmospheric impacts. Journal of Geophysical Research: Atmospheres, 124, 13005– 13025. https://doi.org/10.1029/2018JD029878

Staff, Science X. “Wildfire Smoke Can Carry Microbes That Cause Infectious Diseases.” Phys.org, Phys.org, 18 Dec. 2020, phys.org/news/2020-12-wildfire-microbes-infectious-diseases.html.

“The Danger of Wildland Fire Smoke to Public Health.” EPA, Environmental Protection Agency, 27 Dec. 2018, www.epa.gov/sciencematters/danger-wildland-fire-smoke-public-health.

“Wildfires: How Do They Affect Our Water Supplies?” EPA, Environmental Protection Agency, 7 Jan. 2020, www.epa.gov/sciencematters/wildfires-how-do-they-affect-our-water-supplies.

Wildfire: Review of Life, Property, and Economic Damages

Jessie Liu

Introduction

The exponential growth of large wildfires in Washington, California, and Oregon in the past two decades culminated in 2020 with the West Coast's worst fire season in at least 70 years. This year saw the destruction of human lives, human health, homes and other structures, as well as a regional decrease in air quality from the wildfire smoke, negative economic impacts, and loss of animal populations. Economists stress that wildfires influence multiple dimensions of the economy, such as loss of businesses, decrease in employment, decline in tourism, and costs associated with wildfire suppression and prevention. In addition, ecologists and environmentalists worry how wildfires inflict lasting damage on species and ecosystems, leading to the forest and wildlife change.

Wildfire Current Issue: Threats to health

Importance of Wildfire Current Issue

It is essential to understand wildfires' threats to human health and property damage because of the dramatic increase in the wildfire season at this moment. Due to the current issue of wildfire, related stakeholders should take actions.

The death toll in the West Coast in 2020 due to wildfires was roughly 46 people in total. Thirty-two of the deaths were in California, 11 in Oregon, and 1 in Washington.[64] Wildfires increase air pollution in surrounding areas and affect regional air quality, negatively affecting the surrounding population's health.[65] According to the BC Centre for Disease Control, wildfire smoke can impact people's respiratory system. The impact of smoke includes eye irritation, "runny nose, sore throat, mild cough, phlegm production, wheezy breathing, or headaches" (BCCDC, 2018).[66] More severely, the increase of PM 2.5 in wildfire smoke can be harmful to the lungs for children, elders, and people with asthma. As addressed by the U.S. National Library of Medicine, there tends to be a close relationship between wildfire smoke and the increased chance of acquiring asthma since there are more hospitalizations for asthma after wildfire smoke exposure in 2016 (Global News, May 2019).

On the other side, studies from the Global news that addressing about human health with wildfire have not shown a clear relationship between wildfire and mental health; however, the

---

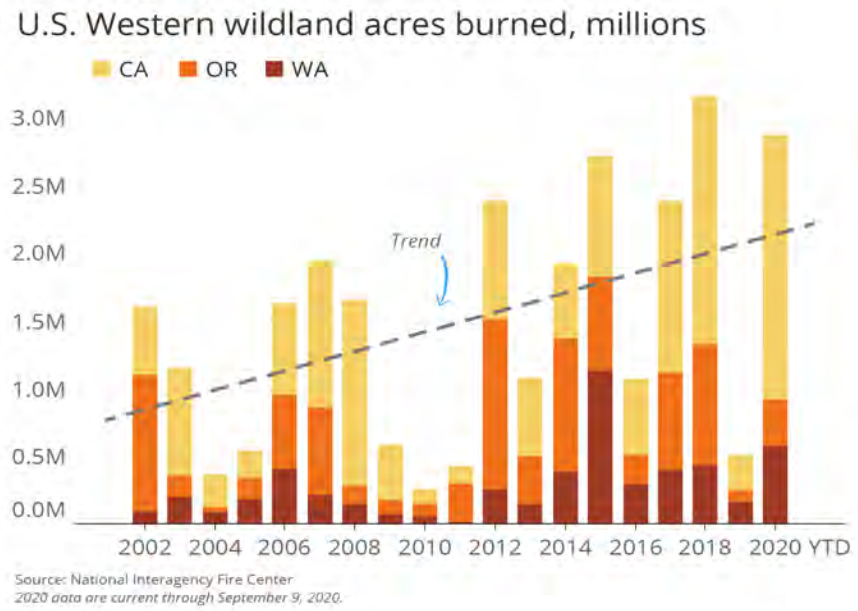
[64] BBC, *Death toll rises in US as wildfire continue in West Coast states*, 2020.

[65] United States Environmental Protection Agency, *Wildfire and Indoor Air Quality,* 2020.

[66] BC Centre for Disease Control, 2018.

PM 2.5 may cause "neuro-inflammation" in the brain, which could negatively influence one's mood and even their cognitive abilities[67] (Global News, May 2019). As a result, there appeared to be an increase in mental hospital visits by those exposed to wildfire smoke in recent years.[68] More importantly, children, older people, and women who are pregnant are more vulnerable to the effects of wildfire smoke because they are more sensitive to the environment surrounding them.

Property Damage



According to a BBC news report on property damage, the wildfires in the western region burned more than 10.2 million acres, with around 41,000 square kilometers of the burnt land being across Napa and Mendocino. These fires destroyed over ten thousand buildings.[69] Wildfires were burning in Oregon, California, and Washington for at least three weeks where they destroyed thousands of homes. According to the National Fire Protection Association data, more than 58,000 fires burned nearly nine million acres across the U.S. in 2008, and around "25,000 structures were destroyed, including 18,137 residences and 229 commercial structures." On the West Coast, California had the highest number of structures lost due to the sheer number of wildfires, "the Mendocino Complex, Carr, Camp and Woolsey fires" (NFPA, 2019). As the National Interagency Fire Center states that, there were about 57,000 more wildfires in 2020 than in 2019. More than "10.3 million acres" were burned in 2020, compared to the "4.7 million acres that were burned by wildfires in 2019," and these wildfires destroyed approximately 10,000 structures. [70] (Figure 1. Acres burned per year by wildfires in California, Oregon, and Washington.) Figure 1 shows an obvious trend in the rapid increase of acres burned by wildfire in West Coast states. The particularly large areas burned in California in 2017, 2018, and 2020

---

[67] Global News, 2019.

[68] Global News, 2019.

[69] BBC, *Death Toll Rises in US as Wildfires Continue in West Coast States,* 2020.

[70] National Interagency Fire Center, 2019.

caused many thousands of people to be evacuated and thousands to lose their homes. In 2020, for example more than 70,000 were required by a state of emergency to flee their homes in places such as Napa, Sonoma, and Shasta, and resulted in thousands of people being forced to evacuate. Moreover, the wildfires caused a lot of in-home destruction including broken windows, damaged roofs, fabrics, walls, and furniture. Because of this, the potential for property damage has risen drastically. Many of the survivors have nothing to come back to after the wildfires ravage their communities.

Economic Damages

Importance of Economic Damages

The burning of wildfire has been affecting the national and local economy from many perspectives. There is a need to emphasize these costs and damages due to wildfire in the western regions because the result of large wildfires tends to have negative impacts and disruptions to local economies.

Economic Impact on Property

Due to the increase of wildfire, there would be a huge impact on the economic side as well. The wildfires in 2020 cost over "$19.884 billion" in these damages, which contained "$3.384 billion in fire suppression and $16.5 billion in property damage" [71] (BBC, Sept 2020). Additionally, the wildfires demolished millions of acres of land and drove a portion of local businesses to shut down.[72] Wildfires significantly impact the ability of a business to operate, and many find it difficult, if not impossible, to reopen following a wildfire." At the same time, wildfires can also impact the value in properties. Due to the extensive amount of damage that wildfires can cause, there is often a dramatic drop in the prices of real estate in the areas where said wildfires wreaked havoc. It is inferred that the condition of community infrastructure negatively influences the market demand. According to Tommy Tengs' research, a land broker and doctorate from Harvard, land values in the affected area are likely to decrease between 3% to 23% after a significant wildfire (Teng, 2019).[73]

The financial cost of wildfires can vary from fire suppression and prevention to the loss of revenue in business, and the increase in insurance that inevitably follows. It is clear that the economic impacts of wildfires have lasting repercussions. Costly repairs will be required for places where wildfires have burned down buildings and damaged infrastructure. Furthermore, some economic damages are burning timber, making tourism displeasing, and decreasing

---

[71] BBC, *Death Toll Rises in US as Wildfires Continue in West Coast States,* 2020.

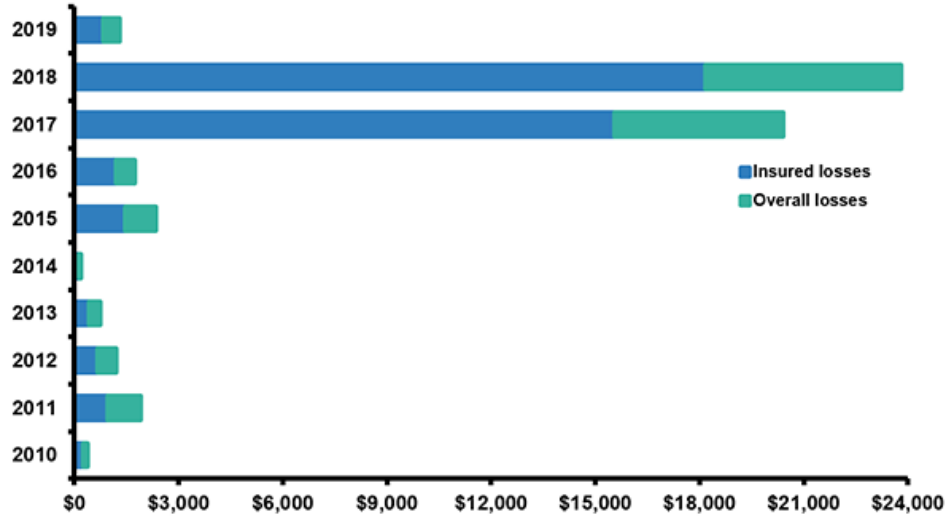
[72] Tengs Tammy, *Effect of Wildfire on Land Prices*, 2019

[73] Tengs Tammy, *Effect of Wildfire on Land Prices*, 2019.

agricultural production. On top of that, wildfires also drop the revenue and tourist's population down by reducing tourism to the National or State Parks by affecting everything from restaurants and small local businesses. The western regions are famous and popular for national parks which California is the host to 9 national state parks. Earlier this year the park closed due to the pandemic, but it has been forced to remain closed as a result of the poor air quality in the area from the surrounding fires. As a result, the number of tourists would be heavily reduced due to the circumstances (Lenhart, 2019). [74]

Additionally, fire insurance is getting more costly due to the common wildfire season in the Western regions. That being the case, we can approximately calculate these economic costs by examining the insurance claims after each wildfire. According to the Insurance Information Institute, one of the costliest wildfires was the Camp Fire that occurred in California in 2018. The cost of insurance due to the damage from this wildfire was easily over "$8.5 billion."[75] So far, California has the highest economic impact, around 14% of the whole nation, due to the vast wildfire and adding up other Western states such as Oregon, Washington State, and Idaho accounts for 19% of U.S economic output, which would be a financial setback and make these wildfires costly.

As the costs for insurance rise, it becomes increasingly difficult for individuals and business owners to afford insuring their properties. As a result, local businesses and residents would need to implement stricter building code and higher insurance premiums. Local businesses' loss also experienced negative shipping, employee productivity, and facilities, which drove the economic damage to a more dreadful level. In the long run, these wildfires have long-lasting fiscal repercussions (Wack, 2020). [76]



(Figure 2. Overall insurance loss in the western regions due to wildfire)

---

[74] Lenhart, *How the California Wildfire Are Impacting Tourism,* 2019.

[75] Insurance Information Institute, 2018.

[76] Wack, 2020.

Stakeholders & Liability

The states and the government are the main stakeholders in assisting the recovery process following wildfire season. The state is responsible for public safety local fire agencies' integrated endeavors. As wildfires occur, the state will need to expect additional insurance claims for matters related to the losses to infrastructure, local assistance aids, and fire equipment expenditure to the local fire department. The recovery process is an essential part in recuperating after such financial losses. Wildfire suppression is a range of firefighting strategy often used to suppress wildfires. Fire suppression is a way to extinguish fires through the application of certain substances, and it is essential for putting out wildfires (Key Stone Protection Co, 2019).[77] For most of the time, the fire suppression system will automatically release the application of an external substance to extinguish the fire. The four essential fire suppression includes "Clean Agent, Carbon Dioxide, industrial systems, and restaurant, in which the Clean Agent fire suppression utilizes chemical reagents that do not harm the environment to blow out the fire. Carbon Dioxide fire suppression systems implement the colorless, odorless gas CO2 to extinguish fires. Differently, industrial fire suppression systems utilize dry chemicals and restaurant fire suppression systems use wet chemicals that are faster than dry chemicals to extinguish the fire. (Key Stone Protection Co, 2019).[78] The wildfire-trained professionals construct fire lines, suppress flame, and extinguish flames and heat to protect natural wilderness.

In the past decade, California experienced a total cost of fire suppression of over $43 million and 1.8% of the total economic loss. Additionally, California spent around $39.5 million on the "Catastrophic Event Memorandum Fund" to repair facilities, infrastructure, and other resource damages (Diaz, 2012).[79] With the help of federal aid on wildfire suppression, an understanding of the financial impact left by wildfires assists the communities, and policymakers, in the policy decision process which serves to help economies to recover.

Overall Economic Impact and Loss

According to the U.S Forest Service, the result of large wildfires tends to be short-term negative impacts and long-term disruptions to local economies. For example, the lost economic activity in San Diego was around "10% based on gross productivity," and this was caused by the loss of business buildings and a "$32.5 million drop in tourism" (Diaz, 2012).[80] Furthermore, drawing from a project on the local economic impacts of large wildland fires in the Western U.S. by the University of Oregon, wildfires cause instability and unpredictability in employment and the labor market**.** This causes local employment and wages in a county to increase during

---

[77] Key Stone Protection Co, *What are fire suppression system and how do they work?* 2019.

[78] Key Stone Protection Co, *What are fire suppression system and how do they work?* 2019.

[79] Diaz, 2012.

[80] Diaz, 2012.

wildfire season in particular. Simultaneously labor market disruptions from the countless wildfires are "outweighed by the employment that the suppression effort generates in the short term." The local economy is affected by increasing around 9 percent of wildfire suppression in the county where the wildfire happened, and the local spending differed between "0 to 39 percent" (University of Oregon, 2019).[81] As a result, regional economics were significantly impacted by the suppression cost due to wildfire. On average for every million dollars spent locally, local employment rates increased by 1%. Overall, the increased frequency and intensity of wildfires is shown to cause economic instability in local communities. The aftermath of wildfire can have negative effects on agriculture, infrastructure, residential and commercial property, public health, and well-being.

Influences of Wildfires on Animal Populations

Understanding the influence on animal population is also crucial because the consequence can be serious when the animal habitat is being threatened due to the raging wildfire.

Wildfires have an impact on animals as well. Wildfires significantly impact the habitats available to wildlife, thereby making critical needs such as access to food, water, and shelter difficult to obtain. The change of environment and ashes that follow a wildfire often causes wildlife to migrate leading to further disruptions in neighboring ecosystems. A serious consequence of wildfires is habitat loss because after the burning of wildfire, birds will fly away, and small animals may burrow underground in order to attempt escape from the smoke.[82]

(Figure 3. An owl seeks refuge from advancing wildfire. KATU News, 2019).[83]

---

[81] University of Oregon, 2019.

[82] Oregon Department of Fish & Wildlife, *Wildfire and Its Impact on Fish and Wildlife.*

[83] KATU News, *How is wildfire being affected by Oregon's fires?* 2019

Wildfires change the characteristics of habitats across a multitude of landscapes. After the wildfire has destroyed a particular region, there is a shortage of food and shelter for wildlife. Moreover, surface insect populations, such as grasshoppers, tend to decrease.[84] The flying insects may be more vulnerable to the destruction of wildfires than other animals because they are attracted to heat or smoke, ending with many grasshoppers being incinerated in great numbers. However, other insect populations like bark beetles tend to increase after a fire (Barkley, Aug 2019). There is no official data or documented wildfire cases that have indicated the decline or loss of entire populations or species.[85] In particular, the ecologists worry the loss of habitat could imperil species with small populations or restricted ranges, and that incinerated ecosystems will fail to rebound in a warming climate, leading to permanent landscape changes.

Conclusions: Concerns and related support

To summarize, the wildfire situation in western regions represents a domain of series and accelerating risk. Such risk extends into many areas, including those involving human lives, property, and well-being, and those that pertain to the health and sustainability of forests, grasslands, and wildlife populations. Moreover, the realm of risk linked to wildfires is also shared by towns and cities that are not near the areas of burning but tens, even hundreds of miles away. This is due to the potential for smoke to invade communities and large metropolitan areas with toxic air pollution that may be continually replenished for weeks or even months during fire season.

In total, wildfire risk can divide into several categories:

- The burning of wildfire can negatively impact human lives and living qualities with the destruction cost by wildfire. Wildfire has led to the death of innocent resident and firefighters in the past few decades. Moreover, the wildfire smoke can also post health threats to people who expose to the burning wildfire and cause inflammation that affects other parts of the body.
- Wildfires also negatively affect homes, other properties and building structures. They could easily get damaged or burned due to the physical threats that wildfires pose.
- Moreover, the emergence of wildfire also influences the economy from many perspectives. Wildfire impact multiple dimensions of the economy, such as loss of businesses, decrease in employment, decline in tourism, and costs associated with wildfire suppression and prevention.
- In the end, wildfires affect the animal population and habitats available to wildlife, which makes critical needs such as access to food, water, and shelter difficult to obtain.

---

[84] Surviving Wildfire, *Wildfire and Wildlife Habitat,* 2019.

[85] Barkley, Aug 2019.

With the increase in wildfire growth in recent years, the large wildfire can worsen human lives and properties, and has a negative impact on the economy. Exposure to a wildfire can also cause problems with people's respiratory systems which could cause inflammation that affects other parts of the body, such as asthma and other internal irritations. At the same time, homes and other properties easily get damaged or burned due to the physical threats that wildfires pose. Overall, the result of large wildfires tends to have short-term negative impacts and long-term instability to local economies. This includes a decline in business, revenue, and tourism in both national and state parks. The wildfires significantly impact animal populations and their habitats. With federal assistance and local governmental organizations on wildfire suppression, the recovery process could mitigate some negative effects through an initial burst of spending that creates positive economic gains. Understanding the impact on economies will help many communities and policymakers better anticipate and manage policy decisions that assist local economies hurt by wildfires.

Works Cited

"Death Toll Rises in US as Wildfires Continue in West Coast States." *BBC News*, BBC, 13 Sept. 2020, www.bbc.com/news/world-us-canada-54130785.

"Forest Economics and Policy." *SRS*, www.srs.fs.usda.gov/econ/disturbance/local-impact/.

Surviving-Wildfire. "Wildfire and Wildlife Habitat." *Surviving Wildfire*, 27 Aug. 2019, surviving-wildfire.extension.org/wildfire-and-wildlife-habitat/.

"Wildfire and Its Impact on Fish and Wildlife." *Wildfire and Its Impact on Fish and Wildlife | Oregon Department of Fish & Wildlife*, myodfw.com/articles/wildfire-and-its-impact-fish-and-wildlife.

"Wildfire and Smoke Damage: How Do They Affect Your Home?" *911 Remediation*, 30 Oct. 2019, 911remediation.com/wildfire-smoke-damage-affect-home.

(www.dw.com), Deutsche Welle. *West Coast Fires Will Cost US ECONOMY Dearly: DW: 17.09.2020*. www.dw.com/en/economic-impact-california-wildfires-us-west-coast/a-54956210.

Disasterphilanthropy.org, disasterphilanthropy.org/disaster/2020-california-wildfires/.

Ecosystem Workforce Program. ewp.uoregon.edu/largefires/content.

Facts + Statistics: Wildfires. www.iii.org/fact-statistic/facts-statistics-wildfires#:~:text=More%20than%2010.3%20million%20acres,structures%20and%20killing%2031%20people.

Holm, Stephanie M., et al. *Health Effects of Wildfire Smoke in Children and Public Health Tools: A Narrative Review*. 20 Sept. 2020, www.nature.com/articles/s41370-020-00267-4.

"How Smoke from Fires Can Affect Your Health." *EPA*, Environmental Protection Agency, 14 Jan. 2021, www.epa.gov/pm-pollution/how-smoke-fires-can-affect-your-health#:~:text=The%20biggest%20health%20threat%20from,even%20linked%20to%20premature%20death.

Jesse Ferreras. *Wildfire Smoke Can Harm Your Lungs, Your Heart, and Maybe Even Your Mental Health: Research*. 1 June 2019, globalnews.ca/news/5336828/health-effects-of-wildfire-smoke-research/.

Sommer, Lauren. *Millions of Homes Are at Risk of Wildfires, but It's Rarely Disclosed*. 21 Oct. 2020, www.npr.org/2020/10/21/924507691/millions-of-homes-are-at-risk-of-wildfires-but-its-rarely-disclosed.

Tengs, Tammy, and About Tammy TengsBroker/Owner of Land22 Real Estate. *Effect of Wildfire on Land Prices*. 21 June 2019, buyingandsellingland.com/effect-of-wildfire-on-land-prices/.

News, KATU. “How Is Wildlife Being Affected by Oregon's Fires? 'Mother Nature Runs on Change'.” *KATU*, KATU, 12 Sept. 2017, katu.com/news/local/how-is-wild-animals-being-affected-by-oregon-wildfires-fires-department-fish-wildlife-odfw.

“What Are Fire Suppression Systems and How Do They Work?” *Keystone Fire Protection Co.*, 21 Aug. 2019, www.keystonefire.com/blog/what-are-fire-suppression-systems-and-how-do-they-work/.

“Wildfires and Indoor Air Quality (IAQ).” *EPA*, Environmental Protection Agency, 28 Dec. 2020, www.epa.gov/indoor-air-quality-iaq/wildfires-and-indoor-air-quality-iaq#:~:text=During%20a%20wildfire%2C%20smoke%20can,outdoor%20air%20unhealthy%20to%20breathe.&text=Smoke%20is%20made%20up%20of,smoke%20is%20from%20fine%20particles.

Wildfire. www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire.

Mercer, D., Pye, J., Prestemon, J., Butry, D., & Holmes, T. (2000). Economic effects of catastrophic wildfires: Assessing the effectiveness of fuel reduction program for reducing the economic impacts of catastrophic forest fire events. Joint Fire Science Program, Topic 8 of the Research Grant, Ecological and Economic Consequences of the 1998 Florida Wildfires. Retrieved from www.floridaforestservice.com/publications/ jointfiresciences/ jfspdf/economic_effects.pdf

Rahn, M. (2009). Wildfire Impact Analysis, Fire Impact Analysis, Spring 2009. San Diego, CA: San Diego University. Retrieved from http://universe.sdsu.edu/ sdsunewscenter/images/ rahn2009fireanalysis.pdf

Future Risks and Trends

Chanyuan Yu

Introduction

Risk and probabilities

Risk can be succinctly defined as "measure of the probability and consequence of uncertain future events". Wildfires present risks to fire responders, policymakers, and the public. There are many types of risks associated with the management of wildfire, such as health risks, economic costs, and the immediate threat fire poses to WUI communities physically. Understanding wildfire management risks is necessary not only for mitigation but also for the active defense of WUI communities. It is important for the members of the fire management community (environmentalists, hazard incident teams, the Forest Service, or the U.S. Fire Administration as a whole) to have a common understanding of these risks so that they can collectively manage fire as safely, effectively, and efficiently as possible.[86]

Wildfire Risks

The Risks and Consequences of Wildfires

Wildfire risk has rapidly increased for a range of different populations, and there is every indication that this will continue in the future. Affected communities include not only those threatened by fire itself, but those subject to wildfire smoke tens and even hundreds of miles away, including major metropolitan areas. As major wildfires have increased in number, size, and severity over the past two decades, the level of risk has grown considerably. Moreover, because people continue to move into the wildland-urban interface (WUI), this level has risen even more rapidly than previously anticipated. These trends show every sign of continuing in the near-term, with the probability of dangerous wildfires growing due to the impacts of climate change. Providing detailed reports on the potential consequences of fire is necessary to depict the risks that can impact the lives of responders and civilians, infrastructures, properties, or natural resources such as wildlife habitat and timber.[87] It is important to understand the likelihood of a wildfire to burn, the probability of that wildfire burning within a specific region, the number of occurrences of the wildfires each year; the contact of an entity, asset, resource, geographic area

---

[86] Matthew Thompson, Tom Zimmerman, Dan Mindar, Mary Taber. "Risk Terminology Primer: Basic Principles and a Glossary for the Wildland Fire Management Community" (Rocky Mountain Research Station. U.S. Department of Agriculture, 2016), 1-2.

[87] Thompson, Zimmerman, Mindar, Taber, 2.

with a potential exposure to the fire; the likely damage produced through this exposure; the public health risks; the methods that can be used directly to reduce the loss of that wildfire; and the risks that persist despite fire management efforts in order to estimate the future liabilities of wildfires in the western region.[88]

The damage wildfire causes can touch on the subjects of how wooden structures may be highly susceptible to. But prescribed burns are also necessary. Plants like Eucalyptus have cones or fruits that can only open to release seeds after the heat of a fire has physically melted the resin.[89] Wildfires can result in substantial ecological benefits such as stimulating regeneration or seed release. mineralizing nutrients, reducing encroachment, and creating suitable habitat conditions.[90]

After carefully analyzing and evaluating the probability of a wildfire, a set of coordinated processes of activities that identify, monitor, assess, prioritize, and control the risks of said wildfire is necessary for proper risk management. Risk management identifies the types of decisions that need to be made and should be performed at all levels.[91] Lastly, it is critical to recount accountability when creating realistic wildfire management options. For instance, attempting to extinguish every fire no matter how small would expose fire responders to dangerous situations, and would foreclose opportunities for ecological benefit. Aggressively suppressing all fires in frequent-fire forests could lead to fuel leftovers and future hazard.[92] Therefore, analyzing and managing risks efficiently would help in reducing unnecessary loss in the future.

Climate Change and Wildfire Risk

Climate change and the chemicals it produces cause severe health concerns

Climate change and its effects on temperatures, aridity, length of the fire season, and lightning occurrence are important to consider. Wildfire combustion produces particulate matter as well as multiple chemicals including the CH_4, N_2O, and CO, as well as CO_2, nitric oxide, VOC_s, and methyl bromide. All of which promote global warming by either enhancing tropospheric O_3 or destroying stratospheric O_3. The carbon released is stored in vegetation in the atmosphere. The wildfires that burned from 2002 to 2006 had an estimated annual CO_2 emission of 213 million metric tons for the contiguous United States.[93] Currently the average emissions

---

[88] Thompson, Zimmerman, Mindar, Taber, 7-12

[89] Melissa Petruzzello, "Playing with Wildfire: 5 Amazing Adaptations of Pyrophytic Plants" (Britannica.com).

[90] Thompson, Zimmerman, Mindar, Taber, 2.

[91] Thompson, Zimmerman, Mindar, Taber, 4-5

[92] Thompson, Zimmerman, Mindar, Taber, 5

[93] Bruce Johansen, *Climate Change: An Encyclopedia of Science, Society, And Solutions*, Steven I Dutch (Amenia, NY: Salem Press, 2016), 27.

from wildfires reached 5.41 metric gigatons annually in the U.S. according to the report of the Union of Concerned Scientists in 2020.[94] The potential risks to exacerbate global warming with this contribution of greenhouse gases can in turn create a hotter, drier environment—which leads to larger, more devastating wildfires.

Wildfires generate a significant volume of particles in the form of smoke, ash, and soot. Such particulate matter, especially when very small in size, constitutes a form of toxic air pollution and is known to cause serious health effects, with such effects increasing the longer particles remain in the air. Most people will recover quickly from the exposure of wildfire smoke, however the people with respiratory or cardiovascular diseases, children, elders, pregnant women, and outdoor workers have greater risk of experiencing health effects.[95]

There are also potential climate impacts from wildfire smoke that increase in importance the longer such smoke continues to be produced. Particle color influences whether energy is absorbed or reflected—that fire-related clouds absorb and block sunlight so that their tropospheric effects are either absorbed to produce warming (dark particles) or reflected to cause cooling (light particles). The dark particles from soot reduce the reflectivity of the frozen surface while enhancing sunlight absorption if it settles out of the atmosphere onto snow or ice.[96] The results are heating, acceleration of melting of the snow or ice, and global warming eventually.

WUI Growth

The WUI has the fastest growing housing rate domestically.

Wildfires can move into the wildland-urban-interface (WUI) quickly, burning homes and sites of development frequently, as well as destroying man-made materials in addition to natural fuels. The WUI is the area where a high concentration of people are at the greatest threat due to the proximity of flammable wildland.[97] The growth rate is faster than any of the forest land cover categories at a 33% rate with an occupation of 770,000km^2 in 2010**.** Additionally, there are no signs that the rapid development of communities in close contact with wildlands will stop in the coming years.[98] This expansion of populations into wildlands poses a challenge for fire management**.** Houses built before the onset of uncontrollable wildfires complicate methods of fire management as well due to the protected equipment and the residents had to be evacuated

---

94 Johansen, 27.

95 Susan Lyon Stone, Jason Sacks, Peter Lahm, Alison Clune, Lewis Radonovich, Miki Wayland, Maria Mirabelli. "Wildfire Smoke: A Guide For Public Health Officials" (Seattle, WA: University of Washington workshop, 2019), 1.

96 Johansen, 27.

97 Stone, Sacks, Lahm, Clune, Radonovich, Wayland, Mirabelli, 1.

98 Volker Radeloff, David Helmers, Anu Kramer, Miranda Mockrin, Patricia Alexandre, Avu Bar-Massada, Van Butsic, Todd Hawbaker, Sebastian Martinuzzi, Alexandra Syphard. "New analyses reveal WUI growth in the U.S." (Northern Research Station: U.S. Department of Agriculture Forest Service, nrs.fs.fed.us/data/wui/).

when the wildfire landed.[99] There are more than 1.75 million people living in the WUI within the western region and are not interested in giving up their comforts today, not until after COVID.[100]

The number of houses within the burned areas is also a strong indication of how the expansion of development in forested regions can exacerbate wildfire problems. By 1990, there were only 177,000 houses within the perimeters of the fires occurred in the subsequent 25 yards, but there were more than 286,000 housing units in the same perimeters by the end of 2010 with an increase of 62%.[101] Also, wildfires that begin in the WUI do not always stay in the WUI. Fires within this area can quickly become a threat to the homes and structures at the edges of cities—burning and ultimately destroying city dwellers' homes.[102] The loss of vegetation and wildland areas due to the rapid development of WUI also increases wildfire risks.

The Abundance of Fuel

Overabundance of fuels increases the magnitude of wildfires

Besides climate change and WUI growth, there are also severe accumulations of biomass. The amount of fuel available determines the fire behavior directly. Low volumes of fuel can result in low intensity, creeping fire; and large volumes of fuel can result in an extreme fire that is difficult to control. On the other hand, heat is produced while fuel is burning, releasing the energy proportional to the intensity of fire.[103] Therefore, overabundance of fuel can cause the duration of wildfires to significantly increase, threatening both the lives of fire responders and civilians.

Different types of fuels often bring out different levels of wildfires. Grasses for instance, are 1-hour fuels, and they are light and flashy compared to trees and dead logs when wildfires burn on top of them.[104] As summer wears on, fires can burn through a lot of heavily forested land. Many of them are not as easy to control or contain as grass fires are. However, grass fires are usually faster to spread. Fires spread twice as fast in grass than they do in bushes.[105] In the

---

[99] Radeloff, Helmers, Kramer, Mockrin, Alexandre, Bar-Massada, Butsic, Hawbaker, Martinuzzi, Syphard, nrs.fs.fed.us/data/wui/.

[100] Chuck Dinerstein, "Why Is The West Coast In Flames?" (American Council On Science And Health, acsh.org).

[101] Volker Radeloff, David Helmers, Anu Kramer, Miranda Mockrin, Patricia Alexandre, Avu Bar-Massada, Van Butsic, Todd Hawbaker, Sebastian Martinuzzi, Alexandra Syphard, Susan Stewart, "Rapid growth of the US wildland-urban interface raises wildfire risk" (Riverside, CA: Proceedings of the National Academy of Sciences of the United States of America, 2017, pnas.org).

[102] Radeloff, Helmers, Kramer, Mockrin, Alexandre, Bar-Massada, Butsic, Hawbaker, Martinuzzi, Syphard, nrs.fs.fed.us/data/wui/.

[103] "Fuel's Effect on Fire Behavior" (Auburn, Alabama: University of Auburn, auburn.edu/academic/forestry_wildlife/fire/fuels_effect.htm).

[104] Allie Weill, "Fuel Matters: Why Wildfire Behavior Depends on What's Burning" (San Francisco, CA: KQED, kqed.org, 2018).

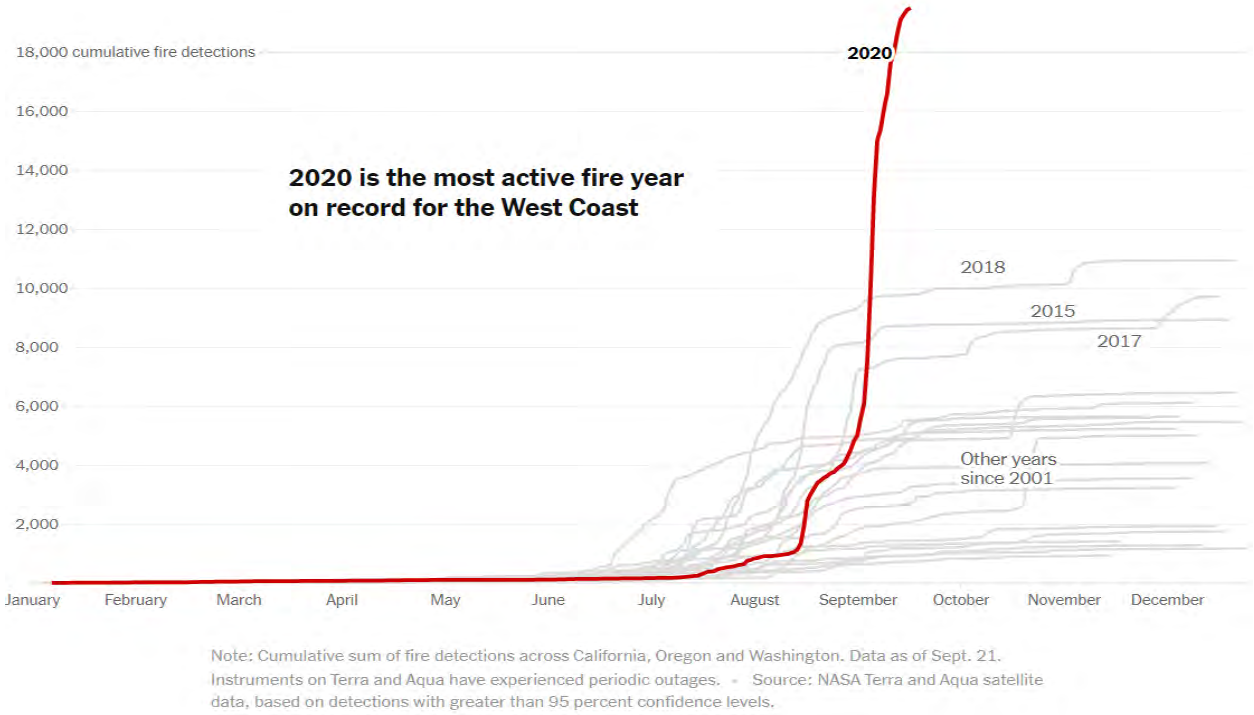
[105] Weill, kqed.org.

Bay Area and coastal California, shrubs, grass, and forests come together in a patch of fuel types.[106] Reduction of fuel makes it easier to fight the fire, but sometimes the risk of ignition is increased as a result. Now the overabundance of widespread non-native grassland causes much more frequent wildfires today in the western region than they did in history. [107]

Trends of Wildfires in the West Coast

The season for wildfires is lengthening

Last year, the worst fire season was recorded in history with an unsurpassed number of wildfires occurring in the western region. The NYT has a report indicating that the "season is part of a long-term trend toward more frequent, more devastating fires in the West that shows no sign of slowing down". There are over five million acres burned in California, Oregon, and Washington up until September of 2020.[108] More than two dozen people died because of these wildfires, and hundreds of thousands of buildings and constrictions were destroyed.[109]



(*The chart above indicates the cumulative fire detections of the West Coast from 2000-2020,

---

[106] Weill, kqed.org.

[107] Weill, kqed.org.

[108] Blacki Migliozzi, Scott Reinhard, Nadja Popovich, Tim Wallace, Allison McCann, "Record Wildfires on the West Coast Are Capping a Disastrous Decade" (New York City, NY: The New York Times Co., nytimes.com, 2020).

[109] Migliozzi, Reinhard, Popovich, Wallace, McCann, nytimes.com.

with the steep growing of wildfire detections after 2017.)[110]

Since 2017, the trend for wildfires is increasing strength and with the year 2020 breaking every existing record as the graph above shows. Some areas, like those in the Bay area as well as nearby Seattle, never recovered from the previous wildfire season and are still recuperating ecologically.[111] The data from the National Interagency Fire Center demonstrates that the number of acres burned annually across Washington, Oregon and California has increased sixfold compared with the average numbers between 1950 and 2000.[112] As a product of climate change and the overabundance of fuels, fire seasons are lengthening. If it continues to grow as the rate in the graph above, the cumulative fire detections are likely to grow in the next decades if no intervention occurs. Air qualities will continue to decrease, and public health is of significant concern. Wildfire trends are likely to worsen as the number and severity direction as the number and severity of fires increases each year. [113]

Conclusion

Future Risks of Wildfires for the West Coast

Decades of fire suppression and global warming along with the expansion of the WUI, built the groundwork for increased risks related to wildfires. Many of the interrelated human causes that shape the fire regimes are avoidable, or at least regulatable. The overall western region is at a critical point**.** The costs in lives, damage to communities, and loss of wildlife are likely to increase over time without some level of intervention.

- While 95% of wildland-fires are “human made”, it has torched more than five million acres in California, Oregon, and Washington with 286,000 units of housing burned in 2010.[114]
- There is a 33% increasing rate of WUI development,[115] with 1.75 million people not willing to give up comfort zones in the WUI.[116] There is more damage and loss expected to threaten humans and wildlife living in the surrounding areas.
- The buildup of fuels to suppress the wildfires and the spread of economically destructive fires is as important as the roles of climate change and poorly devised development in the

---

[110] Migliozzi, Reinhard, Popovich, Wallace, McCann, nytimes.com.

[111] Migliozzi, Reinhard, Popovich, Wallace, McCann, nytimes.com.

[112] Migliozzi, Reinhard, Popovich, Wallace, McCann, nytimes.com.

[113] Migliozzi, Reinhard, Popovich, Wallace, McCann, nytimes.com.

[114] Radeloff, Helmers, Kramer, Mockrin, Alexandre, Bar-Massada, Butsic, Hawbaker, Martinuzzi, Syphard, Stewart, pnas.org.

[115] Radeloff, Helmers, Kramer, Mockrin, Alexandre, Bar-Massada, Butsic, Hawbaker, Martinuzzi, Syphard, nrs.fs.fed.us/data/wui/.

[116] Dinerstein, acsh.org.

wildland-urban interface.

- Lengthening wildfire seasons threatens even more lives, with firefighters, civilians, and wildlife being the main victims also put more risks on both fire responders and managers, causing issues when evacuating civilians.
- The toxin-laden smoke and chemicals produced during the wildfires makes air conditions hazardous for millions. The futures of wildfires are unimaginably complex and unpredictably dangerous without effort on large-scale mitigations.[117]

---

[117] Sara Jensen, Guy McPherson, *Living with Fire: Fire Ecology and Policy for the Twenty-first Century* (Oakland, CA: University of California Press, 2008), 136.

Works Cited

Thompson, Matthew P., et al. *Risk Terminology Primer: Basic Principles and a Glossary for the Wildland Fire Management Community*, U.S. Dept. of Agriculture, Forest Service, Rocky Mountain Research Station, 2016.

Petruzzello, Melissa. "Playing with Wildfire: 5 Amazing Adaptations of Pyrophytic Plants." *Encyclopædia Britannica*, Encyclopædia Britannica, Inc., www.britannica.com/list/5-amazing-adaptations-of-pyrophytic-plants.

Johansen, Bruce E. *Climate Change an Encyclopedia of Science, Society, and Solutions*. ABC-CLIO, an Imprint of ABC-CLIO, LLC, 2017.

Stone, Susan Lyon., et al. *Wildfire Smoke: A Guide For Public Health Officials*, *AirNow.gov*, 2019, www.airnow.gov/wildfire-smoke-guide-publications/.

Radeloff, Volker.; Helmers, David.; Kramer, Anu.; Mockrin, Miranda.; Alexandre, Patricia.; Bar-Massada, Avi.; Butsic, Van.; Hawbaker, Todd.; Martinuzzi. Sebastian.; Syphard, Alexandra.; Stewart, Susan. "Northern Research Station". *New Analyses Reveal WUI Growth in the U.S. - Northern Research Station, USDA Forest Service*, www.nrs.fs.fed.us/data/wui/.

Dinerstein, Chuck. "Why Is the West Coast In Flames?" *American Council on Science and Health*, 17 Sept. 2020, www.acsh.org/news/2020/09/14/why-west-coast-flames-15024.

Radeloff, Volker.; Helmers, David.; Kramer, Anu.; Mockrin, Miranda.; Alexandre, Patricia.; Bar-Massada, Avi.; Butsic, Van.; Hawbaker, Todd.; Martinuzzi. Sebastian.; Syphard, Alexandra.; Stewart, Susan. "Rapid Growth of the US Wildland-Urban Interface Raises Wildfire Risk." *PNAS*, National Academy of Sciences, Mar. 2018, www.pnas.org/content/115/13/3314. 27.

"Fuel's Effect on Fire Behavior." *Fuel's Effect on Fire*, University of Auburn. www.auburn.edu/academic/forestry_wildlife/fire/fuels_effect.htm.

Weill, Allie. "Fuel Matters: Why Wildfire Behavior Depends on What's Burning." *KQED*, Oct. 2018, www.kqed.org/science/1928625/__trashed-35, 23.

Migliozzi, Blacki, et al. "Record Wildfires on the West Coast Are Capping a Disastrous Decade." *The New York Times*, The New York Times, 24 Sept. 2020, www.nytimes.com/interactive/2020/09/24/climate/fires-worst-year-california-oregon-washington.html.

Jensen, Sara E., and Guy R. McPherson. *Living with Fire: Fire Ecology and Policy for the Twenty-First Century*. University of California Press, 2008.

Human Risk Mitigation 1: Land Use, Building Materials, Community Action, and Social Considerations

Annika Souter

Introduction

Recent extreme wildfires throughout the West Coast have highlighted the consequences of community development in the wildland-urban interface (WUI). Such consequences have included thousands of homes burned, businesses destroyed, and hundreds of homeowner and firefighter fatalities. Urban sprawl and population growth have made the WUI the fastest growing land use type in the United States. The increasing number of people in this setting defines a serious concern, because the highest number of homes burn within WUI communities due to their proximity to wildland fuels, thus defining a situation where risk mitigation is crucial.

Decades of wildfire suppression has called for the need to revise the framework communities use in order to mitigate the risk and potential damages. Applying such framework requires an understanding of the interconnectedness between wildfires, home ignitions, and mitigation opportunities. Among these opportunities are planning tools that have become increasingly more available for communities, local governments, fire emergency planners, and other official personnel. Planning tools consist of land use regulations and comprehensive development which would feature zoning, subdivision ordinances, building codes, and voluntary community programs. As the threat of wildfires becomes increasingly unavoidable, it is essential that communities are proactively planning in order to protect infrastructures and civilians.

Land Use Planning and Regulations

Land use planning and regulations allow for wildfire mitigation to be integrated into a community's goals for growth, sustainability, and resilience.

Land use planning as a form of risk mitigation can reduce wildfire damage by regulating developments that are built in fire-prone areas. This is done by taking into account wildfire effects on the design and placement of proposed developments. Wildfire mitigation tactics can be embedded into communities through the use of planning for new developments and making modifications in existing communities. The inevitability of wildfires has required communities in the WUI to evolve in order to protect homes and other costly infrastructure. To successfully do so communities in the WUI have implemented a land use planning framework that includes community policies, zoning, subdivision ordinances, and building codes as tools to address the wildfire threats and mitigate risks to their communities.

Community Plans and Policies in the WUI

Many communities who face the threat of wildfires have implemented or updated policies that provide guidance on mitigating fire risks. Embedding mitigation policies into community plans allows for these communities to grow as they work towards combating fire threats, especially in the WUI. Although community plans are nonregulatory, they demonstrate a town or city's intentions for growth, safety, and sustainability.[118]

A Community Wildfire Protection Plan (CWPP) is a community-based plan that identifies local wildfire risk, what is at risk, and actions the community must take to address its wildfire risk.[119] CWPPs have been in practice across the United States since 2003 when the Health Forests Restoration Act (HFRA) was signed into law. The HFRA gives statutory incentives to organizations such as the United States Forest Service (USFS) and the Bureau of Land Management (BLM) for supporting and reviewing fuel reduction as well as other forest management projects in local communities.[120] The HFRA lays out three key requirements that all CWPPs must follow: 1. Show collaboration between local and state agencies, in consultation with federal agencies and other interested parties; 2. Identify and prioritize fuel treatments to reduce hazardous fuel areas; 3. Recommend strategies to reduce the ignitability of structures.[121]

In 2005, Missoula County adopted a CWPP that was put in motion by the Missoula County Office of Emergency Services. The CWPP was later updated in 2018 to work in tandem with the 2017 Pre-Disaster Mitigation Plan for Missoula County and City that had the goal of reducing wildfire risk within the WUI.[122] The updated CWPP involved the collaboration of numerous stakeholders including citizens, privatized organizations, along with local, state, federal, and tribal agencies who represented different areas of expertise and perspectives.[123] The collaboration of stakeholders substantiates the county's common goal of increasing its capacity for resilient landscapes, fire adapted communities, efficient response capabilities, and learning to live alongside future wildfires.[124] The 2018 CWPP laid out an Action Plan for the community to achieve this goal by holding stakeholders accountable and identifying mitigation tasks at hand.

---

[118] Barrett, Kimiko. "Land Use Planning Can Reduce Wildfire Risk to Homes and Communities." *Headwaters Economics*, 11 Aug. 2020, headwaterseconomics.org/natural-hazards/land-use-planning-wildfire/.

[119] Mowery, Molly, and Kelly Johnstone. Community Planning Assistance for Wildfire, 2018, *COMMUNITY WILDFIRE PROTECTION PLAN MISSOULA COUNTY, MONTANA*, www.missoulacounty.us/home/showdocument?id=30120.

[120] Ibid.

[121] Ibid.

[122] Ibid.

[123] Ibid.

[124] Ibid.

Each action has at least one proposed lead responsible for advancing the action, a priority level for implementation, a desired timeframe for completion, and any additional notes relevant to support the action.[125] Other counties' CWPP documents have executed similar goals in regards to mitigating wildfire risks, including Austin and Travis Counties in Texas, where they have successfully created a joint city-county coalition to lessen potential fire hazards.[126] The adoption and implementation of both Missoula and Austin-Travis County's CWPP are the consequences of local partnerships and drive to coordinate collective action against the risk of wildfires.

Successful implementation of community plans and policies have been noted in other states as well where CWPPs have been embedded into large-scale plans for counties. In Boulder County, Colorado a comprehensive plan was amended in 2018 which included an entire section dedicated to wildfire hazard protection. This section laid out policies jointly developed by Boulder County officials and local fire department representatives with the goal of guiding land use decision making and regulation in regards to fire protection.[127] The policies are addressed via land use development codes describing the county's growth management and development plans, development standards, wildfire education programs, evolving building codes, and even site safety assessments for property owners.[128] Boulder County's progressive and successful comprehensive plan has proven the county's commitment to mitigating fire risks to communities.

Despite these advancements, further planning is needed to address the growing threat that wildfires pose to communities. Thus in 2014 the Community Planning Assistance for Wildfire (CPAW) was launched as a multi-disciplinary team that brings expertise from a variety of perspectives concerning land use planning.[129] CPAW reviews and analyzes the previously described Comprehensive Plans and Land Use Development Codes and integrates them with other risk mitigation plans; the tools that CPAW employs in its communities are customized based on the needs of the area, examples are displayed in Figure 1.[130] Chelan County, Washington is one of 39 communities across 14 states that have participated in and benefitted

---

[125] Ibid.

[126] Rasker, Ray, and Kimiko Barrett. Headwaters Economics, 2016, *Land Use Planning to Reduce Wildfire Risk: Lessons from Five Western Cities*, headwaterseconomics.org/wp-content/uploads/Planning_Lessons_Full_Report_Print.pdf.

[127] Boulder County Land Use Department, 2018, *BOULDER COUNTY COMPREHENSIVE PLAN "Goals, Policies, and Maps Element"*, as- sets.bouldercounty.org/wp-content/uploads/2017/07/bccp-comprehensive-plan-amended-2017.pdf.

[128] Rasker, Ray, and Kimiko Barrett. Headwaters Economics, 2016, *Land Use Planning to Reduce Wildfire Risk: Lessons from Five Western Cities*, headwaterseconomics.org/wp-content/uploads/Planning_Lessons_Full_Report_Print.pdf.

[129] Community Planning Assistance for Wildfire. "Land Use Planning." *Community Planning Assistance for Wildfire*, Headwaters Economics, 6 Feb. 2019, cpaw.headwaterseconomics.org/what-we-do/land-use-consulting-advice/.

[130] Barrett, Kimiko. "Land Use Planning Can Reduce Wildfire Risk to Homes and Communities." *Headwaters Economics*, 11 Aug. 2020, headwaterseconomics.org/natural-hazards/land-use-planning-wildfire/.

from CPAW's program.[131] Among the CPAW recommendations for Chelan County are to define the wildland-urban interface (WUI) and implement a WUI risk assessment program; to adopt a WUI code; and to update the comprehensive plan to support wildfire activities.[132]

Figure 1: Land use planning tools used by CPAW for reducing wildfire risk in WUI communities. (Source: Barrett, Kimiko. "Land Use Planning Can Reduce Wildfire Risk to

[131] Hernandez, Patricia. "Wildfire Risk to Communities: A Tool to Understand, Explore, and Reduce Risk." *Headwaters Economics*, 9 Apr. 2020, headwaterseconomics.org/natural-hazards/wildfire-risk-to-communities/.

[132] Mowery, Molly, et al. "Recommendations for Chelan County, WA." *Community Planning Assistance for Wildfire (CPAW)*.

Community plans and policies provide the foundation for community growth and the implementation of wildfire risk mitigation techniques. It requires forward-thinking principles and empowers communities in the protection of critical infrastructure, assets, and resources--including the lives of civilians.[133] The plans and policies that have been applied in Montana, Texas, Colorado, and Washington are also applicable to other states that have not taken the same steps towards mitigating wildfire risk.

Zoning

Zoning is one of the strongest and most common types of land use planning tools for regulating development. It provides a unique opportunity to mitigate wildfires by prescribing what the land in specific areas can be used for and to what extent it can be developed; these areas can be commercial, residential, or agricultural districts.[134] Zoning regulations in WUI communities are often embedded into the CWPP in order to protect the structures and lives within these areas. Some zoning districts, such as overlay zoning districts, require specific standards in certain areas compared to general zoning regulations and can be used to mitigate wildfire risks by placing specialized regulations on an area that is of particular concern.[135] Regulations in overlay districts often supersede the existing standards of general zoning. Communities in the West Coast Region of the United States that have successfully used overlay zoning as tools for mitigating wildfire risks include Flagstaff, Arizona and Santa Fe, New Mexico.

In Flagstaff, the goal of zoning codes is to create an approach that reinforces the unique areas of the city rather than a "one size fits all" approach that is used by most conventional zoning codes.[136] Part of the city's specialized zoning codes is the Resource Protection Overlay Zone (RPO) which applies to areas of the city that warrant protection of natural resources.[137] Division 10-50.90 of Flagstaff's Zoning Code lays out the purpose and standards of the RPO and

---

[133] Barrett, Kimiko. "Land Use Planning Can Reduce Wildfire Risk to Homes and Communities." *Headwaters Economics*, 11 Aug. 2020, headwaterseconomics.org/natural-hazards/land-use-planning-wildfire/.

[134] Ibid.

[135] Ibid.

[136] Flagstaff Zoning Code: Preamble: A Place-Based Approach to Zoning, section 10-00.010, Introduction. City of Flagstaff, Oct. 2011. https://www.codepublishing.com/AZ/Flagstaff/html/Flagstaff10/Flagstaff1000000.html#10.00.060. Accessed 3 Feb 2021.

[137] Flagstaff Zoning Code: Division 10-40.50: Overlay Zones, Section 10-40.50.030 Overlay Zones. City of Flagstaff, Nov. 2020. https://www.codepublishing.com/AZ/Flagstaff/html/Flagstaff10/Flagstaff1040050.html#10.40.50. Accessed 3 Feb 2021

states that one of the goals is to manage healthy and sustainable forests to reduce fire risk.[138] This standard of the RPO overrides other general zoning regulations or resource preservation standards of the area which allows the removal of trees for wildfire risk reduction despite forest preservation efforts.[139]

In Santa Fe, similar overlay zoning codes have been implemented to mitigate the risk of wildfires in the WUI. Santa Fe's escarpment district, where the foothills climb sharply into the plateaus, is the city's leading priority for implementing wildfire protection efforts.[140] The Escarpment Overlay District was established in 1992 to reduce erosion and stormwater runoff, while preserving the aesthetic appeal of the area.[141] However the steep, forested area is also at highest risk of wildfire. Therefore the regulations of the overlay zone were modified in order to aid in wildfire risk protection. In the Escarpment Overlay District, multidisciplinary specialists work together to oversee the city's escarpments in order to strike a balance between competing interests of development and wildfire mitigation. One of the goals of the overlay district, laid out in article 14-5.6 section A of Santa Fe's Codes of Ordinances, is to reduce the risk to life and health of residents in the escarpment by reducing wildfire risk.[142] The Escarpment Overlay District aids in mitigating wildfire risks via establishing criteria on landscaping such as planting vegetation with lower burn risks, prohibiting development in specific areas like the plateaus, and also regulating structure development where allowed.[143] In regulating the erection of structures, development applications in the escarpment overlay district undergo strict evaluations. The city also performs a more thorough site assessment in order to further reduce wildfire risk and damages in new development.[144] This allows the local government to mitigate wildfire threats to residents and structure through monitoring the development of the area. The Escarpment Overlay District also has the right to regulate other matters as are appropriate to preserve the environment of the escarpment overlay district, meaning that city planners, WUI specialists, and local fire personnel may place additional regulations on the district that are not stated in the Code of

---

[138] Flagstaff Zoning Code: Division 10-50.90: Resource Protection Standards, Section 10-50.90.010 Purpose. City of Flagstaff, Feb. 2016. https://www.codepublishing.com/AZ/Flagstaff/html/Flagstaff10/Flagstaff1050090.html#10.50.90. Accessed 3 Feb 2021

[139] Rasker, Ray, and Kimiko Barrett. Headwaters Economics, 2016, *Land Use Planning to Reduce Wildfire Risk: Lessons from Five Western Cities*, headwaterseconomics.org/wp-content/uploads/Planning_Lessons_Full_Report_Print.pdf.

[140] Barrett, Kimiko. "Land Use Planning Can Reduce Wildfire Risk to Homes and Communities." *Headwaters Economics*, 11 Aug. 2020, headwaterseconomics.org/natural-hazards/land-use-planning-wildfire/.

[141] Community Planning Assistance for Wildfire. "Santa Fe, New Mexico." *Community Planning Assistance for Wildfire*, 15 Jan. 2020, cpaw.headwaterseconomics.org/project/santa-fe-new-mexico/.

[142] Santa Fe, New Mexico - Code of Ordinances: Chapter 14 - Land Development - Article 14.5 - Overlay Zoning Districts, Article 14-5.6 - Escarpment Overlay District. NO PUB DATE. https://library.municode.com/nm/santa_fe/codes/code_of_ordinances?nodeId=CH14LADE_ART14-5OVZODI. Accessed 3 Feb 2021.

[143] Ibid.

[144] Barrett, Kimiko. "Land Use Planning Can Reduce Wildfire Risk to Homes and Communities." *Headwaters Economics*, 11 Aug. 2020, headwaterseconomics.org/natural-hazards/land-use-planning-wildfire/.

Ordinances if needed.[145] For instance, the city may reduce or negate requirements to plant trees in order to reduce fuel and the risk of wildfire.

Subdivision Ordinances

Through stipulating layouts of new developments, subdivision ordinances can mitigate wildfire impacts by requiring multiple access points, sufficient water supply, vegetation requirements, and setback distances.[146] Unlike zoning as a regulatory tool for mitigating wildfire threats, subdivision ordinances focus on regulating developments that are at greater risk of wildfires.

In many WUI communities, trained personnel use a wildfire hazard severity rating system based on a model developed by the National Fire Protection Association (NFPA) in order to determine what homes and subdivisions are at high-risk.[147] The NFPA model determines rating for individual components of wildfire risk in regards to vegetation, home construction materials, road design and access, water availability, and signage and compiles them into a hard overall score.[148] Once a subdivision is labeled as high risk, modifications can be made to protect the community from wildfire hazards. A modified version of the NFPA rating system produced by the University of Arizona Cooperative Extension provided a Home Wildfire Hazard Severity Checklist to determine the severity of wildfire risks in a given neighborhood or subdivision, and included community design, vegetation, topography, roofing material, existing building construction, available fire protection, and utilities as factors that affect hazard severity.

Pre existing subdivisions can improve their wildfire severity hazard rating by managing vegetation, repairing roads to adequately accommodate firefighter access and resident evacuation, installing proper signage, servicing utilities, maintaining adequate water supply, and implementing building codes.

New subdivision developments provide an opportunity to build a low risk community from the beginning. Fire protection standards can be incorporated into the initial design and layout of these developments, ensuring a greater level of protection against wildfires. An analysis of hundreds of homes that burned in Southern California fires showed that housing arrangement

---

[145] Santa Fe, New Mexico - Code of Ordinances: Chapter 14 - Land Development - Article 14.5 - Overlay Zoning Districts, Article 14-5.6 - Escarpment Overlay District. NO PUB DATE. https://library.municode.com/nm/santa_fe/codes/code_of_ordinances?nodeId=CH14LADE_ART14-5OVZODI. Accessed 3 Feb 2021.

[146] Barrett, Kimiko. “Land Use Planning Can Reduce Wildfire Risk to Homes and Communities.” *Headwaters Economics*, 11 Aug. 2020, headwaterseconomics.org/natural-hazards/land-use-planning-wildfire/.

[147] Haines, Terry K., et al. *The National Wildfire Mitigation Programs Database: State, County, and Local Efforts to Reduce Wildfire Risk*. www.srs.fs.usda.gov/pubs/ja/ja_haines003.pdf.

[148] Ibid.

strongly influenced the effects of wildfires on structure damage and loss.[149] Subdivision regulations can require cluster developments and direct them away from high wildfire risk areas toward lower wildfire risk areas. Cluster developments like this discourage dispersed developments that often back onto forest boundaries. This type of development preserves open space, provides an adequate buffer between structures and potential fuel, and makes evacuation and response easier for firefighters. Although cluster developments are susceptible to high-density structure-to-structure loss due to urban conflagration, this pattern of development significantly reduces wildfire risks.[150] However, subdivisions that also require structures to follow strict building codes such as defensible space and use of fire-resistant materials effectively reduce both urban and wildfire hazards.

Building Codes

Building codes are a regulatory tool that govern the design, construction, and maintenance of structures and serve as the basis for ensuring safety in the community.[151] Due to counties not having the authority to enact building codes, local administrations are responsible for implementing and enforcing them, oftentimes found embedded into subdivision regulations or CWPPs.[152] To do so, local administrations commonly adopt blueprint building codes maintained by the International Code Council (ICC) or the National Fire Protection Association's Standards for Protection of Life and Property from Wildfire, and then modify the codes to better fit the needs of the city.[153] The ICC released the International WUI Code (IWUIC) in 2003 with the aim of mitigating wildfire hazards to life and property.[154] The IWUIC contains provisions addressing fire spread, accessibility, defensible space, water supply and more for buildings constructed near wildland areas.[155] The document is updated every three years and is amended based on recent wildfire science and knowledge [156]; it was last updated in 2018.[157] The most

---

[149] Syphard, Alexandra D, et al. "Land Use Planning and Wildfire: Development Policies Influence Future Probability of Housing Loss." *PloS One*, Public Library of Science, 14 Aug. 2013, www.ncbi.nlm.nih.gov/pmc/articles/PMC3743760/#pone.0071708-Syphard3.

[150] Ibid.

[151] Rasker, Ray, and Kimiko Barrett. Headwaters Economics, 2016, *Land Use Planning to Reduce Wildfire Risk: Lessons from Five Western Cities*, headwaterseconomics.org/wp-content/uploads/Planning_Lessons_Full_Report_Print.pdf.

[152] Ibid.

[153] Barrett, Kimiko. "Land Use Planning Can Reduce Wildfire Risk to Homes and Communities." *Headwaters Economics*, 11 Aug. 2020, headwaterseconomics.org/natural-hazards/land-use-planning-wildfire/.

[154] Ibid.

[155] International Code Council. "2018 International Wildland-Urban Interface Code®." *International Code Council*, 2018, shop.iccsafe.org/2018-international-wildland-urban-interface-coder.html.

[156] Barrett, Kimiko. "Land Use Planning Can Reduce Wildfire Risk to Homes and Communities." *Headwaters Economics*, 11 Aug. 2020, headwaterseconomics.org/natural-hazards/land-use-planning-wildfire/.

[157] International Code Council. "2018 International Wildland-Urban Interface Code®." *International Code Council*, 2018, shop.iccsafe.org/2018-international-wildland-urban-interface-coder.html.

recent update includes regulations on defensible space as well as ignition-resistant construction requirements.

One of the most thorough reviews of this topic published by the U.S. Government Accountability Office (GAO) in 2005 stated that the two most effective measures for protecting structures from wildfires are: 1. creating and maintaining a 30 to 100 foot buffer around a structure called a defensible space or home ignition zone (shown in Figure 2)[158], and 2. using fire resistant roofs and vents. These tools are also laid out in the 2018 IWUIC update. Analysis of past fires have shown that managing vegetation and reducing or eliminating flammable material within a 30 to 100 foot radius around a structure removes fuels that could bring fire in contact with the structure's exterior. For instance in the 1981 Atlas Peak Fire in California, 5 out of 111 structures that were damaged or destroyed had sufficient defensible space, while in contrast 91 out of 111 structures that were damaged or destroyed did not have adequate defensible space. Creating and maintaining a defensible space can also reduce the heat generated by crown fires, which is particularly harmful to structures. Experiments done by the GAO showed that all of the walls located 33 feet from crown fires were damaged during a series of experimental fires, however no observable damage occurred on walls located 66 feet from the crown fires.[159] An article by the National Academy of Sciences, using the term home ignition zone (HIZ), stated that fuel treatment of fire-prone areas alone without HIZ treatment and maintenance will result in structure loss from inevitable wildfire exposure.[160] The creation

Figure 2: A Ross Valley home with a maintained defensible space that survived a wildfire (Source: Ross Valley Fire Department. *Defensible Space*. www.rossvalleyfire.org/

---

158 Ross Valley Fire Department. *Defensible Space*. www.rossvalleyfire.org/prevention/defensible-space.

159 GAO. *U.S. Government Accountability Office*, 26 Apr. 2005. www.gao.gov/assets/160/157597.pdf.

160 Calkin, David E., et al. "How Risk Management Can Prevent Future Wildfire Disasters in the Wildland-Urban Interface." *PNAS*, National Academy of Sciences, 14 Jan. 2014, www.pnas.org/content/111/2/746.

of a defensible space sets structures up to withstand wildfire hazards in high risk WUI communities.

According to a report done by GAO, using available fire-resistant roof-covering materials along with screening vents, reduces the likelihood of embers igniting a structure. Materials such as asphalt composition, clay, concrete, metal, slate, treated wood products, and even synthetics, such as rubber, can all be used to achieve a "class A" roof certification (via standardized tests approved by The American National Standards Institute/Underwriters Laboratories Inc. and the American Society for Testing and Materials). In Boulder County, local officials recognized the value in such regulations and implemented them before they became standard in national building codes. Since the 1998 Lefthand Canyon Fire and 1989 Black Tiger Fire in Boulder, the county has amended their building codes first by introducing roof material requirements, and later integrating other building code regulations such as window screens. Regulating roof material substantially reduced wildfire risk by limiting the likelihood of an ember igniting the roof.[161]

Building codes as a tool for mitigating wildfire risks can be applied to pre existing structures just as they are applied to new structures. Defensible space, fire-resistant window screens and glass, fire-resistant roofing materials, and properly screened attic vents are all fire protection measures that can be installed on preexisting structures. Fire-resistant windows such as those constructed of double-paned glass, glass block, or tempered glass can prevent windows from breaking and fire from entering a structure. Specific roof materials such as those discussed above and fire resistant cap sheets (the layer underneath shingles) can be installed to prevent embers entering through cracks in the roof. Installing fire-resistant screening vents to blocks embers from entering attic spaces are necessary in the prevention of structural ignitions. In new structures, fire-resistant building materials such as fiber-cement, brick, stone, metal, and stucco for walls, siding, decks, and doors also play an important role in protecting structures from wildfires.[162]

Community Action: Voluntary Programs

***By getting community members who are affected by the hazards of wildfires involved in mitigation efforts, communities in the WUI are more aware of wildfires and the preventative measures necessary to defend their community*.**

Voluntary community programs have served as tools for mitigating wildfire risks in WUI communities. There are numerous organizations at the federal, state, and local level that are

---

[161] GAO. *U.S. Government Accountability Office*, 26 Apr. 2005. www.gao.gov/assets/160/157597.pdf.
[162] GAO. *U.S. Government Accountability Office*, 26 Apr. 2005. www.gao.gov/assets/160/157597.pdf.

working to increase the use of protective measures to prevent home ignitions caused by wildfires including Firewise Communities/USA and the Ready, Set, Go! program.[163]

The primary effort of community action and volunteer programs is Firewise Communities/USA. Firewise Communities/USA is a national program that is designed to encourage residents in wildfire-prone areas to take voluntary actions in the protection of their homes and neighborhoods.[164] The program is the result of a cooperative effort among the National Fire Protection Association (NFPA), the U.S. Forest Service, the Department of the Interior, and state forestry organizations.[165] It works by teaching residents the basics of wildfire behavior and asking community members to join together to create a plan of action and begin making their homes safer prior to the threat of a wildfire.[166] The program has recognized more than 100 communities in 26 states as "Firewise" communities, meaning they have met the criteria of assessing risks, developing plans, and taking action to mitigate wildfire threats.[167]

Because it seeks to increase voluntary use of protective measures, the Firewise Communities program requires homeowner and community involvement in order to be successful.[168] Firewise communities engage in a variety of risk mitigation activities including maintaining defensible space around structures; in Truckee, California, a Firewise community, residents take part in voluntary activities such as clearing defensible space around structures, and can schedule an inspection by local fire personnel. Encouraging community members to join voluntary programs such as Firewise Communities/USA can be a part of a city's CWPP; in the CWPP for Missoula County, they promote participation in the program to encourage neighborhood activities and local recognition.[169] Missoula County's CWPP also promotes delivering Ready, Set, Go! (RSG) program messages to residents to aid in preparation for wildfires and potential evacuations.[170] The RSG program works in collaboration with Firewise USA and other existing wildfire education efforts. The program provides tools and resources for local fire departments to use as they aid residents in understanding wildfire risk reduction.[171] Los Angeles is another city that promotes the RSG program. On the Los Angeles Fire Department

---

[163] Ibid.

[164] Steinberg, Michele. "Firewise Forever? Voluntary Community Participation and Retention in Firewise Programs." *Proceedings of the Second Conference on the Human Dimensions of Wildland Fire*, doi:https://www.nrs.fs.fed.us/pubs/gtr/gtr-nrs-p-84papers/11steinberg-p-84.pdf.

[165] Ibid.

[166] Ibid.

[167] GAO. *U.S. Government Accountability Office*, 26 Apr. 2005. www.gao.gov/assets/160/157597.pdf.

[168] Ibid.

[169] Mowery, Molly, and Kelly Johnstone. Community Planning Assistance for Wildfire, 2018, *COMMUNITY WILDFIRE PROTECTION PLAN MISSOULA COUNTY, MONTANA*, www.missoulacounty.us/home/showdocument?id=30120.

[170] Ibid.

[171] International Association of Fire Chiefs. *Ready, Set, Go!*, 2020, www.wildlandfirersg.org/s/iafc2/about-20Y3m0000004EdyEAE?language=en_US.

(LAFD) website, information on the RSG program provides a step by step guide to ensure people are prepared in the case of an approaching wildfire. Many hillside communities within Los Angeles are in the paths of potential, future wildfires and as risk increases LAFD states it is important to plan, prepare, and stay aware by following the RSG program's guides.[172] The RSG program and Firewise USA are just a few examples of the voluntary community action programs that members of WUI communities are a part of; other small scale voluntary programs exist as local committees that work towards the similar goal of mitigating wildfire risks.

Social Considerations

Wildfires give way to many social ramifications including displacement of people and the consideration of tribal lands both of which are essential for communities to examine.

An issue that many WUI communities face is post-fire homelessness caused by wildfires. In November 2018, the Camp Fire that decimated the town of Paradise in Butte County, California claimed 86 lives, destroyed or damaged some 18,000 structures, and caused $16.5 billion in damage.[173] This left thousands of people homeless in an area that was already experiencing a housing shortage[174] of less than 2% vacancy prior to the wildfire.[175] This level of destruction in an area already suffering a housing shortage further undermines housing affordability and renders many homeless.[176] Post-fire homelessness is not a phenomenon unique to Butte County, it affects every community who faces wildfire disasters causing already inflated rents to drastically increase during periods of low vacancy. In 2017 when wildfires hit Sonoma County, 5% of the housing stock was destroyed and the median rent increased by 35% in the weeks following the fire.[177] Six months post fire, tens of thousands of people remained displaced with the 1,200 beds in homeless shelters having been at capacity since before the fires.[178] People with more financial flexibility may be able to afford a place to live during the early days of

---

172 Los Angeles Fire Department. "Ready, Set, Go!" *Los Angeles Fire Department*, www.lafd.org/ready-set-go

173 State Bar of California, California Commission on Access to Justice. "Disasters in Rural California: The Impact on Access to Justice." *State Bar of California*, July 2019. https://www.calbar.ca.gov/Portals/0/documents/accessJustice/Rural-Disaster-Policy-Brief.pdf. Accessed 7 Feb 2021.

174 Fung, Vincent. "Displacement and Housing Affordability in the United States." *IDMC*, 1 July 2019, www.internal-displacement.org/expert-opinion/displacement-and-housing-affordability-in-the-united-states.

175 State Bar of California, California Commission on Access to Justice. "Disasters in Rural California: The Impact on Access to Justice." *State Bar of California*, July 2019. https://www.calbar.ca.gov/Portals/0/documents/accessJustice/Rural-Disaster-Policy-Brief.pdf. Accessed 7 Feb 2021.

176 Ibid.

177 Ibid.

178 Ibid.

wildfire disaster recovery, however lower-income individuals are likely to be left to seek housing assistance from the Federal Emergency Management Agency (FEMA) or evacuation centers.

Post-fire homelessness and inflated rent prices cause many people to rely of FEMA assistance. As of March 2019, individuals impacted by the Camp Fire had filed almost 27,000 valid registrations seeking FEMA assistance.[179] FEMA assistance and benefits provide both disaster Housing Assistance and FEMA Direct Housing.[180] FEMA's Direct Housing program supplies Manufactured Housing Units (MHUs) and recreational vehicles (RVs) to residents affected by post fire homelessness.[181] In the case of the 2018 Camp Fire, despite FEMA offering millions of dollars in housing assistance, they encouraged people to search for housing in Sacramento.[182] This forces victims of wildfires to sacrifice their jobs, friends, family, and entire livelihoods in order to secure housing.

Extremely low income communities typically do not have access to entitlements such as FEMA benefits and do not know what other programs are available.[183] Studies show that eligibility for FEMA assistance is often provided based on income.[184] Legal assistance aids in solving this issue and mitigating the spike in post-wildfire homelessness. Legal Aid of Sonoma (LAS) was able to secure temporary housing for a client facing homelesseness after FEMA suspended a program she was receiving assistance through.[185] Ensuring low-income communities have access to the resources they need is an integral piece to equitable post-fire recovery.

Individuals and families who face post-fire homelessness are also subject to other challenges as a result of their displacement. With increased risk in these locations affected by wildfires, updated building codes may require homeowners to rebuild with fire-resistant materials.[186] This could add to the already high cost of living and make it financially impossible for those who have been displaced. However according to a recent study done by Headwaters Economics (Figure 3), building a home to fire-resistant standards costs roughly the same as a

---

[179] Ibid.

[180] Ibid.

[181] Ibid.

[182] Fung, Vincent. "Displacement and Housing Affordability in the United States." *IDMC*, 1 July 2019, www.internal-displacement.org/expert-opinion/displacement-and-housing-affordability-in-the-united-states.

[183] State Bar of California, California Commission on Access to Justice. "Disasters in Rural California: The Impact on Access to Justice." *State Bar of California*, July 2019. https://www.calbar.ca.gov/Portals/0/documents/accessJustice/Rural-Disaster-Policy-Brief.pdf. Accessed 7 Feb 2021.

[184] Ibid.

[185] Ibid.

[186] Fung, Vincent. "Displacement and Housing Affordability in the United States." *IDMC*, 1 July 2019, www.internal-displacement.org/expert-opinion/displacement-and-housing-affordability-in-the-united-states

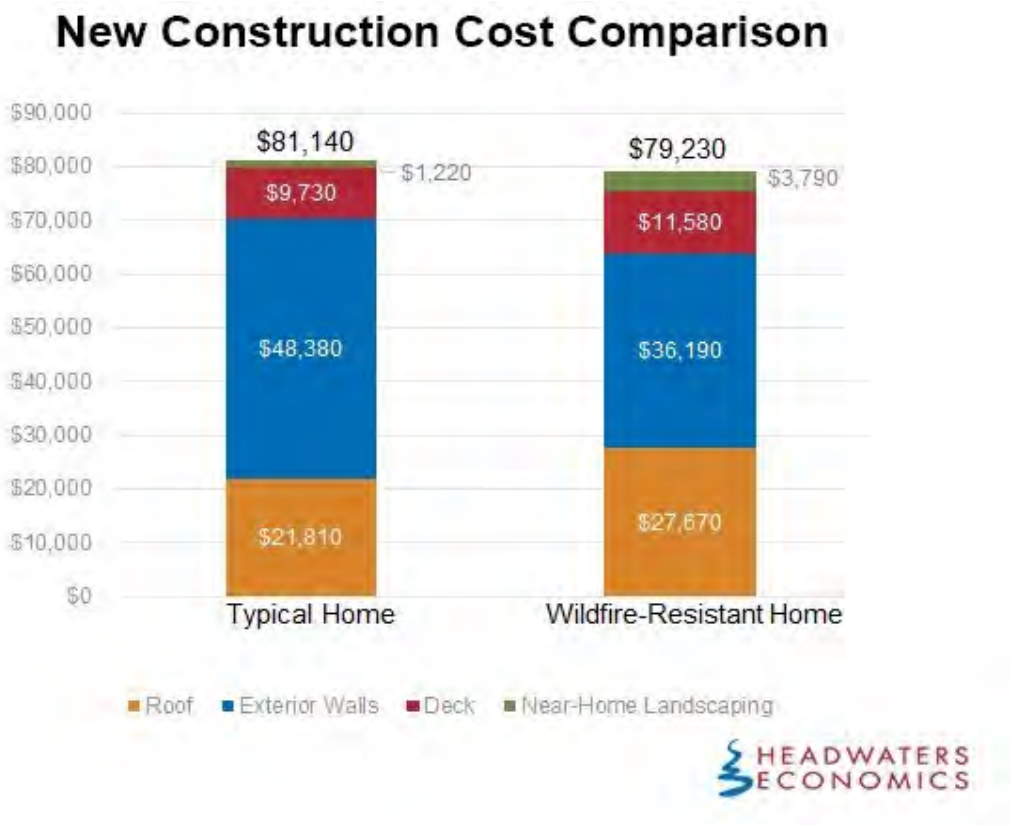


Figure 4: Comparison of new construction cost of a typical home versus a wildfire-resistant home. The model for this report was based on new construction and retrofitting expenses for a three-bedroom, 2,500-square-foot, single-story, single-family home. This model is representative of WUI building styles in southwest Montana (Source: Quarles, Stephen L., Kelly Pohl "Building a Wildfire-Resistant Home: Codes and Costs" *Headwaters Economics*, Nov. 2018, https://headwaterseconomics.org/wp-content/uploads/building-costs-codes-report.pdf.).

traditional, combustible home, and can provide long term benefits for homes in high-risk areas.[187]

Consideration of tribal lands is also necessary for communities facing wildfire risks. Many WUI communities are on tribal lands or have tribal reservations within close proximity. Up until the last 115 years ago before the creation of the United States Forest Service (USFS), Native American tribes had been implementing cultural burning and landscape restoration.[188] For thousands of years, they were able to live off the land while sustaining a healthy ecosystem through prescribed burns which made the forests dependent on human interaction, enabling a co-existence between humans and forests. The knowledge that has been passed down for generations provides a perspective that is crucial for mitigating modern-day wildfire risks.

---

[187] Quarles, Stephen L., Kelly Pohl "Building a Wildfire-Resistant Home: Codes and Costs" *Headwaters Economics*, Nov. 2018, https://headwaterseconomics.org/wp-content/uploads/building-costs-codes-report.pdf.

[188] Lane, Taylor, et al. 2016, *Indigenous Fire Management:Solving California's Catastrophic Drought & Wildfire Problems.*, www.tcrcd.net/fsc/pdf/AMS_159_Wildfire_Article_NFMT.pdf.

Acknowledging the land that their community is occupying, Missoula, Montana created an updated Community Wildfire Protection Plan (CWPP) in collaboration with numerous stakeholders including tribal agencies.[189] In California governments have turned towards indigenous groups for insight to more efficiently and effectively manage their forests.[190] The collaborative efforts between indigenous groups and the state of California could help reverse the effects that wildfires are having on their communities. Similar approaches have been made in Washington State. The Department of Natural Resources (DNR) laid out a 10 year strategic plan for wildfire protection and examined the connection to tribal lands in regards to defending those areas. Several tribes have programs that include suppression resources, prevention, and post-fire Burned Area Emergency Response (BAER) support.[191] The DNR also provides protection of tribal lands under contract or agreements with each respective tribe.[192] Governments at both the local and state levels have been looking towards tribal communities for assistance in wildfire mitigation and have sought to continue building relationships with tribal agencies through these efforts.

Conclusion

There are many opportunities for humans to mitigate wildfire risks in the WUI that lie within regulations of land use and community action. Through the implementation of community planning, zoning, subdivision ordinances, and building codes, WUI communities can successfully do the following:

- Protect their community, structures, and residents
- Adapt to live alongside wildfires
- Move towards growth, resiliency, and sustainability

Local communities have the responsibility to organize against the threats that wildfires present. It is essential for residents and stakeholders in mitigation efforts to work together in implementing the tools discussed above as the threat posed by wildfires increases every year.

---

[189] Mowery, Molly, and Kelly Johnstone. Community Planning Assistance for Wildfire, 2018, *COMMUNITY WILDFIRE PROTECTION PLAN MISSOULA COUNTY, MONTANA*, www.missoulacounty.us/home/showdocument?id=30120.

[190] Lane, Taylor, et al. 2016, *Indigenous Fire Management:Solving California's Catastrophic Drought & Wildfire Problems.*, www.tcrcd.net/fsc/pdf/AMS_159_Wildfire_Article_NFMT.pdf.

[191] Washington State Wildland Fire Protection 10-Year Strategic Plan. Second Edition, Department of Natural Resources, August 2019, https://www.dnr.wa.gov/publications/rp_wildfire_strategic_plan.pdf. Accessed 18 Feb. 2021.

[192] Ibid.

Works Cited

Barrett, Kimiko. “Land Use Planning Can Reduce Wildfire Risk to Homes and Communities.” *Headwaters Economics*, 11 Aug. 2020, headwaterseconomics.org/natural-hazards/land-use-planning-wildfire/.

Boulder County Land Use Department, 2018, *BOULDER COUNTY COMPREHENSIVE PLAN "Goals, Policies, and Maps Element"*, as- sets.bouldercounty.org/wp-content/uploads/2017/07/bccp-comprehensive-plan-amended-2017.pdf.

Calkin, David E., et al. “How Risk Management Can Prevent Future Wildfire Disasters in the Wildland-Urban Interface.” *PNAS*, National Academy of Sciences, 14 Jan. 2014, www.pnas.org/content/111/2/746.

Community Planning Assistance for Wildfire. “Land Use Planning.” *Community Planning Assistance for Wildfire*, Headwaters Economics, 6 Feb. 2019, cpaw.headwaterseconomics.org/what-we-do/land-use-consulting-advice/.

Community Planning Assistance for Wildfire. “Santa Fe, New Mexico.” *Community Planning Assistance for Wildfire*, 15 Jan. 2020, cpaw.headwaterseconomics.org/project/santa-fe-new-mexico/.

Flagstaff Zoning Code: Preamble: A Place-Based Approach to Zoning, section 10-00.010, Introduction. City of Flagstaff, Oct. 2011. https://www.codepublishing.com/AZ/Flagstaff/html/Flagstaff10/Flagstaff1000000.html#10.00.060. Accessed 3 Feb 2021.

Flagstaff Zoning Code: Division 10-40.50: Overlay Zones, Section 10-40.50.030 Overlay Zones. City of Flagstaff, Nov. 2020. https://www.codepublishing.com/AZ/Flagstaff/html/Flagstaff10/Flagstaff1040050.html#10.40.50. Accessed 3 Feb 2021

Flagstaff Zoning Code: Division 10-50.90: Resource Protection Standards, Section 10-50.90.010 Purpose. City of Flagstaff, Feb. 2016. https://www.codepublishing.com/AZ/Flagstaff/html/Flagstaff10/Flagstaff1050090.html#10.50.90. Accessed 3 Feb 2021

Fung, Vincent. “Displacement and Housing Affordability in the United States.” *IDMC*, 1 July 2019, www.internal-displacement.org/expert-opinion/displacement-and-housing-affordability-in-the-united-states.

GAO. *U.S. Government Accountability Office*, 26 Apr. 2005. www.gao.gov/assets/160/157597.pdf.

Haines, Terry K., et al. *The National Wildfire Mitigation Programs Database: State, County, and Local Efforts to Reduce Wildfire Risk*. www.srs.fs.usda.gov/pubs/ja/ja_haines003.pdf.

Hernandez, Patricia. "Wildfire Risk to Communities: A Tool to Understand, Explore, and Reduce Risk." *Headwaters Economics*, 9 Apr. 2020, headwaterseconomics.org/natural-hazards/wildfire-risk-to-communities/.

International Association of Fire Chiefs. *Ready, Set, Go!*, 2020, www.wildlandfirersg.org/s/iafc2/about-20Y3m0000004EdyEAE?language=en_US.

International Code Council. "2018 International Wildland-Urban Interface Code®." *International Code Council*, 2018, shop.iccsafe.org/2018-international-wildland-urban-interface-coder.html.

Lane, Taylor, et al. 2016, *Indigenous Fire Management:Solving California's Catastrophic Drought & Wildfire Problems.*, www.tcrcd.net/fsc/pdf/AMS_159_Wildfire_Article_NFMT.pdf.

Los Angeles Fire Department. "Ready, Set, Go!" *Los Angeles Fire Department*, www.lafd.org/ready-set-go.

Mowery, Molly, and Kelly Johnstone. Community Planning Assistance for Wildfire, 2018, *COMMUNITY WILDFIRE PROTECTION PLAN MISSOULA COUNTY, MONTANA*, www.missoulacounty.us/home/showdocument?id=30120.

Mowery, Molly, et al. "Recommendations for Chelan County, WA." *Community Planning Assistance for Wildfire (CPAW)*.

Quarles, Stephen L., Kelly Pohl "Building a Wildfire-Resistant Home: Codes and Costs" *Headwaters Economics*, Nov. 2018, https://headwaterseconomics.org/wp-content/uploads/building-costs-codes-report.pdf.

Rasker, Ray, and Kimiko Barrett. Headwaters Economics, 2016, *Land Use Planning to Reduce Wildfire Risk: Lessons from Five Western Cities*, headwaterseconomics.org/wp-content/uploads/Planning_Lessons_Full_Report_Print.pdf.

Santa Fe, New Mexico - Code of Ordinances: Chapter 14 - Land Development - Article 14.5 - Overlay Zoning Districts, Article 14-5.6 - Escarpment Overlay District. NO PUB DATE.

https://library.municode.com/nm/santa_fe/codes/code_of_ordinances?nodeId=CH14LADE_ART14-5OVZODI. Accessed 3 Feb 2021.

State Bar of California, California Commission on Access to Justice. "Disasters in Rural California: The Impact on Access to Justice." *State Bar of California*, July 2019. https://www.calbar.ca.gov/Portals/0/documents/accessJustice/Rural-Disaster-Policy-Brief.pdf. Accessed 7 Feb 2021.

Steinberg, Michele. "Firewise Forever? Voluntary Community Participation and Retention in Firewise Programs." *Proceedings of the Second Conference on the Human Dimensions of Wildland Fire*, doi:https://www.nrs.fs.fed.us/pubs/gtr/gtr-nrs-p-84papers/11steinberg-p-84.pdf.

Syphard, Alexandra D, et al. "Land Use Planning and Wildfire: Development Policies Influence Future Probability of Housing Loss." *PloS One*, Public Library of Science, 14 Aug. 2013, www.ncbi.nlm.nih.gov/pmc/articles/PMC3743760/#pone.0071708-Syphard3.

Washington State Wildland Fire Protection 10-Year Strategic Plan. Second Edition, Department of Natural Resources, August 2019, https://www.dnr.wa.gov/publications/rp_wildfire_strategic_plan.pdf. Accessed 18 Feb. 2021.

Risk Mitigation: Human Factors II

Stephany Moreno

Introduction

Humans are responsible for the ignition of 80% of wildfires in the United States[193]. Although decades of fire suppression have influenced the occurrence and intensity of wildfires in recent years, it is people who are more frequently responsible for igniting them. This includes many of the more severe and damaging fires, such as the 2018 Camp Fire in California. In fact, the 2018 Camp Fire resulted from improper electrical transmission maintenance, destroying 153,000 acres of land, killing 85 people, and ravaging 18,800 buildings.[194] Nevertheless, negligence to maintain electrical infrastructure is not the only contributing factor to wildfires. Humans, both inadvertently and intentionally, cause fires. With the rise in fire frequency and severity, human interaction and involvement will undoubtedly result in further destruction for the western region.

*Figure SEQ Figure * ARABIC 1 Aftermath of the Camp Fire (Source: www.usatoday.com)*

The Camp Fire

What could have been prevented and positive outcomes.

Arguably the most media-covered fire in the past decade was the 2018 Camp Fire, which devastated the town of Paradise and Concow (see Figure 1). As reported by multiple articles that quoted from the California Department of Forestry and Fire Protection investigation, the Camp Fire was started by a Pacific Gas and Electricity electrical transmission line, of which was confirmed by PG&E.[195][196] In an investigation conducted by the California Public Utilities Commission's Safety and Enforcement Division (SED), the Camp Fire resulted from mismanagement of the electrical transmission line. PG&E had violated multiple general order rules and public utilities code requirements, leading up to the wildfire.[197] Such violations include not doing thorough maintenance checks and

---

[193] (Jaffe et al.)

[194] (Balaraman)

[195] (Eavis and Penn)

[196] (Eavis)

[197] (*Appendix A SED Incident Investigation Report for 2018 Camp Fire with Attachments*, 2-3)

delaying repairs without proper documentation for the delays.[198] Since there is a lack of documentation, there is no established reason for the delays. Though one likely reason, seeing how PG&E is a corporate company, is to minimize the cost, even if it detriments the environment and the people within. If the maintenance checks had been done properly on the Caribou-Palermo transmission line, one would have found a piece of equipment had failed before it could result in a power line to touch the steel tower and drop molten metal to the ground, sparking the vegetation.[199] Nonetheless, the Camp Fire turned out to be one of the most destructive wildfires in California history because of human negligence.

There is reason to believe the utility company is not the only entity to blame for the Camp Fire. Despite numerous violations of general orders done by PG&E regarding maintenance, California officials and the California Public Utilities Commission (CPUC) failed to enforce state rules that would have helped mitigate further maintenance neglect. According to the CPUC's electric facilities safety audit reports, PG&E constantly violated maintenance and inspection reporting general orders throughout the decade.[200] For instance, in 2010, one violation identified by the CPUC was, "GO 128, Rule 17.1, Design, Construction and Maintenance…The enclosure of the vault at this location was broken creating an unsafe condition because of the minor exposure of PG&E's underground equipment."[201] With the number of violations increasing as the years went by, one can conclude that CPUC did not administer sufficient repercussions to discourage continuous infractions. Furthermore, in the SED investigation, it was discovered that in PG&E's submitted records, PG&E did not perform climbing inspections after repeated problems occurred on the Caribou-Palermo transmission line between 2001 and the date of the Camp Fire.[202] It appears as though the CPUC did not thoroughly review the annual reports of inspections they require from PG&E during those 17 years.[203] Even more damning for the CPUC and PG&E is, "that a climbing inspection of the Incident Tower during that time could have identified the worn C-hook before it failed, and that its timely replacement could have prevented ignition of the Camp Fire."[204] These revelations suggest a weak effective oversight by the state.

In an effort to deter future wildfires, PG&E established the Wildfire Safety Inspection Program (WSP). Through this program, it was discovered there were over 5,000 hazardous

---

198 (*Appendix A SED Incident Investigation Report for 2018 Camp Fire with Attachments*, 2-3)

199 (Fire in Paradise (full film) | FRONTLINE." 4:00)

200 (*Electric Facilities Safety Audit Reports Archive*)

201 (California Public Utilities Commission, 4)

202 (*Appendix A SED Incident Investigation Report for 2018 Camp Fire with Attachments,* 16)

203 (*Inspection and Maintenance Standards*)

204 (*Appendix A SED Incident Investigation Report for 2018 Camp Fire with Attachments,* 16)

conditions on the inspected transmission lines.[205] The program also concluded that at least 10 steel lattice towers had to be replaced, and 12 steel lattice towers needed reinforcement.[206] Additionally, in a shared effort to cover the costs of future wildfires, PG&E alongside Southern California Edison and San Diego Gas & Electric, established the Assembly Bill (AB) 1054. In this bill, the three electric companies contribute $10.5 billion to the wildfire insurance fund and can only use those funds if the company receives an annual safety certification from the CPUC.[207] Requirements for the certification include having effective Wildfire Mitigation Plans that cover a 3-year period, follow CPUC safety protocols, and transparently share data regarding safety inspections among other data.[208] In the case that a wildfire was started by the electrical corporations' equipment, the corporations can only receive the funds if they have followed all safety precautions.[209] On July 12th, 2019, AB 1054 was chaptered after being approved by the California legislature and Governor, formally made law.[210] Though the Camp Fire brought great despair, new programs and bills were created in the aftermath. These programs help to deter wildfires from occurring in the future.

Electricity Infrastructure

The current infrastructure, causes and prevention of wildfires, and new options.

The Camp Fire was not the only wildfire caused by poor maintenance of electrical infrastructure. In fact, "Pacific Gas & Electric Co. power lines have caused more than 1,500 California wildfires in the past six years."[211] PG&E is not the only electrical transmission company in the western region that is a danger to forests in surrounding areas, power lines in dense forests full of fuel due to decades of fire suppression is a major source of concern.

In the United States, the power system contains "more than 7,300 power plants, nearly 160,000 miles of high-voltage power lines, and millions of low-voltage power lines and distribution transformers, which connect 145 million customers."[212] The western region is within the Western Interconnection, one of the three main power grids where electricity is delivered to individuals in the U.S., and spans over 14 states, 2 Canadian provinces, and the upper portion of

---

205 (*Appendix A SED Incident Investigation Report for 2018 Camp Fire with Attachments,* 18)
206 (*Appendix A SED Incident Investigation Report for 2018 Camp Fire with Attachments,* 18).
207 (*Wildfires*)
208 (*Assembly Bill No. 1054*)
209 (*Assembly Bill No. 1054*)
210 (*Assembly Bill No. 1054*)
211 (McFall-Johnsen)
212 (*U.S. electric system is made up of interconnections and balancing authorities*)

Baja California.[213] This power grid spans 136,000 miles of antiquated transmission lines.[214] Construction of these power transmission lines began in the early 1900s, when the demand for electricity grew rapidly after World War I.[215] However, the transmission lines built back then are still withstanding today. For example, the electric tower that sparked the Camp Fire was built between 1919 and 1921, making the tower almost 100 years old.[216] The U.S. Energy Information Administration voiced a need to replace, upgrade, and add new power lines, but there are limitations.[217] Needing approval to build new transmission lines, obtaining rights to land property, and funding hinder the improvement of the Western power grid.[218]

As components of distribution lines age, degrade, and fail, in areas surrounded by dry vegetation, wildfire risk increases considerably. There are multiple ways a wildfire can be started by power lines, the most common way being in close contact with vegetation. A branch or tree that has been allowed to grow too close to a transmission corridor can be dislodged in a storm, resulting in a downed line brushing against the shrubs on the ground. Branches can also have prolonged contact with the electrical lines, eventually igniting the branch. Another mode in which power lines can start a fire is through apparatus failure, as was the case for the Camp Fire. This happens when a component of the distribution tower fails, and after going through a pre-failure period in which arcing and sparking increases, causing "progressive damage that eventually evolves into high-energy arcing or even burns conductors in two, resulting an energized wire on the ground, which provides a ready source of ignition."[219]

*Figure SEQ Figure * ARABIC 3 Eagle Creek Fire (Source: www.oregonlive.com)*

Such transmission power line fires are more likely to occur if hazardous weather conditions, like strong winds, develop. In order to attempt to mitigate this, a procedure commonly done by electrical corporations are Public Safety Power Shutoffs (PSPS) where utilities power down their equipment to avoid igniting fires. The downside is that millions of people lose power during such events, leaving the majority of those impacted vulnerable and without electricity.

---

213 (*Western Interconnection*)

214 (*Western Interconnection*)

215 (*Electricity explained How electricity is delivered to consumers*)

216 (*Appendix A SED Incident Investigation Report for 2018 Camp Fire with Attachments*, 8)

217 (*Electricity explained How electricity is delivered to consumers*)

218 (*Electricity explained How electricity is delivered to consumers*)

219 (*How Do Power Lines Cause Wildfires?*)

Additionally, generators used during PSPS events are diesel fueled, regressing any progress made towards reaching climate change goals.[220]

Replacing wood poles with steel ones in high fire-risk areas have also been discussed. This is called distribution grid hardening, a practice many small electricity corporations like Avista, a Spokane, Washington based utility company, are incorporating. This operation aims to reduce the number of distribution-ignited fires in the electric system. Steel is used instead of wood because it is "more resistant to fire, severe weather (such as high winds) and damage caused by humans and animals [including maintenance neglect]."[221] Moreover, because steel poles are more resistant to fire, the risk of a power outage decreases alongside the duration of power outages. This greatly helps electricity-sensitive buildings and communities like hospitals and nursing homes.

Another solution discussed is the placement of underground power lines. By burying the distribution system underground, the susceptibility risk greatly decreases as vegetation cannot touch the power lines and the power lines are hidden away from rough weather conditions. However, there are two disadvantages in this mitigation method. For one, the costs vastly outweigh overhead power lines. About PG&E's distribution system, it would cost $1.16 million per mile to submerge their system, which is double the cost of setting up overhead power lines.[222] Nevertheless, if this were to be done regardless of cost, the allocation of funding is uncertain. Though the cost may be high, the opportunity cost could be lower as underground power lines do not contribute to the likelihood of wildfires nearly as much as overhead power lines. A second problem with burying electrical lines is the reparation of underground equipment which is extremely challenging. Due to the invisibility of underground power lines, even more attention and money is required to manage and maintain underground infrastructure.[223] Other possible issues include the amount of time necessary to displace all the lines underground exceeds well over one thousand years, and there are environmentally sensitive areas where digging is not permitted.[224]

Direct Human Ignitions

Deterrence of unintentional and intentional arson plus consequences.

Other human ignition sources included in the 80% figure of wildfire ignitions are fireworks, camping, recreation (e.g., all-terrain vehicles), barbecuing in WUI areas, arson, etc. A

---

220 (*Reducing Utility-Related Wildfire Risk, 25*)

221 (*We're doing more to protect against wildfires*)

222 (Baker)

223 (Baker)

224 (Baker)

campfire left unattended, discarding a cigarette on the grass floor, or even a baby shower mechanism can turn into a disastrous wildfire and lead to an expensive consequence. One bizarre case was the El Dorado Fire in 2020, caused by a gender reveal party. Since mitigating human actions is unreasonable, deterrence is used instead to prevent the ignition of wildfires.

In the case of fireworks, they are illegal to set off on Federal lands. Though most, if not all, sporadic and dangerous types of fireworks are illegal in the United States, from the years of 2014 to 2018, there were still 600 cases where fireworks ignited forest, woods, or wildfires.[225] One of which was the Eagle Creek Fire in Oregon that burned 47,000 acres of forest land after a teenager threw fireworks into a canyon.[226] To ensure another such fire does not happen, there are punishment proceedings to dissuade firework usage in forested areas. In the Pacific Northwest, carrying and using any kind of firework in National Forests or any other area administered by the Pacific Northwest Region will be classified as a "Class B misdemeanor, by a fine of not more than $5,000 for an individual or $10,000 for an organization, or imprisonment for not more than 6 months, or both."[227] As for accidentally starting a wildfire, people are still liable to hefty fines and prosecution. The adolescent that started the Eagle Creek Fire was subjected to pay $36.6 million in restitution and was sentenced to 1,920 hours of community service and five years of probation.[228]

The punishment for intentional arson in each state is taken seriously and the consequences of such actions are much harsher. In California, if convicted for arson of forest land, one is subject to a "felony punishable by imprisonment in the state prison for two, four, or six years."[229] In Washington State, arson that impacts forests and firefighters can be categorized in the worst-case scenario as a Class A felony in which the guilty faces at least 20 years of imprisonment in a state correctional institution, or a fine of at most $50,000, or both.[230] As for Oregon, the one at fault of arson in the first degree is given a Class A felony as well. This includes a maximum imprisonment term of 20 years, or a $375,000 fine, or both.[231]

On another note, the Department of Natural Resources in Washington utilizes burn restrictions and Commissioner Order Burn Bans to reduce the likelihood of direct human-ignited wildfires from occurring. A burn restriction and a burn ban indicate that all fire is prohibited in

---

225 (Ahrens)
226 (Wamsley)
227 (*Fireworks prohibited on public lands*)
228 (Wamsley)
229 (*Penal Code Section 451*)
230 (*RCW 9A.48.020: Arson in the first degree.*)
231 (*ORS 161.625¹ Fines for felonies*)

all land covered by the DNR.[232] These are put in place usually when it is extremely hot and there are dry weather conditions. If there is a burn restriction violation, one is subjected to a ticket, prosecution and/or civil action. Additionally, if a fire ignited grows into a wildfire, the one who sparked it is responsible for paying for the fire suppression personnel and equipment used to put out the fire.[233]

A different mitigation tactic for wildfires is education. As people continue to move to the WUI, one would assume the number of direct human-ignited wildfires would increase. However, this is not the case for Washington state as evidence shows a decrease in human-related sparks.[234] According to Dr. Crystal Raymond of the University of Washington Climate Impact Group, the decrease in human ignitions, despite the growing WUI, is a result of the DNR's strong educational campaign on wildfire mitigation.[235] This suggests that education plays a key role in deterring fires started by humans. The DNR plans to continue this education by increasing year-round prevention team personnel who lead fire prevention activities and programs in communities.[236] An example activity is the National Fire Protection Association's Wildfire Community Preparedness Day where individuals of all ages gather to raise awareness and reduce wildfire risks every first Saturday in May every year.[237]

Fire Awareness

Past and present fire education alongside the need for awareness.

After decades of fire suppression in the western region, people have become accustomed to seeing all fires as dangerous and unnecessary. This is a perspective in need of change as fire is a natural part of sustaining a healthy wildlife ecosystem. This mentality was brought up on to children for decades through the Smokey Bear campaign, which encouraged the suppression of all fires, both unnatural and natural. The catchphrase, "Remember... Only YOU Can Prevent Forest Fires" was constantly repeated to children and adults, resulting in the oversaturation of forests and wildfires of greater intensity.

Smokey Bear was created in the 20th century, after the United States entered World War II. The public feared the possibility of the Japanese igniting forest lands with bombs, so the Forest Service, Cooperative Forest Fire Prevention Program, and the War Advertising Council

---

232 (*Burn Restrictions*)
233 (*Burn Restrictions*)
234 (Raymond)
235 (Raymond)
236 (Washington State Wildland Fire Prevention)
237 (*Wildfire*)

*Figure SEQ Figure * ARABIC 4: Smokey Bear Poster (Source: wikipedia.org)*

came together to unite the public in suppressing fires.[238] From then on, the United States practiced a no-tolerance policy towards wildfires. Through decades of Smokey Bear commercials with the same message: fire is bad, human relationship with fire deteriorated from a harmonious one with the indigenous people to discordant. Also, because the commercials were recurring, Smokey Bear became popular among children, and Smokey Bear's ideology was taught in schools. This led to fires continuing to be extinguished, and the forest undergrowth increasing throughout the 20th century, leaving the 21st century with unnatural fuel-loaded forests.

Nowadays, the Smokey Bear campaign is the complete opposite from the 1950s. On the website, Smokey Bear now encourages the use of fire treatments to mitigate wildfires, putting an end to the fire suppression agenda.[239] However, this new approach does not reach the same levels of audience interaction as the one from the mid-1900s. There are a lot less frequent Smokey Bear PSAs than in the past. Nevertheless, the cultural icon demonstrated public awareness campaigns that are consistent can have tremendous power in shaping people's mindsets.

Human relationship with fire differs on each side of the Cascade-Sierra Mountains. The people living on the West side of the cascades (the population centers) are much less aware of fire nature and the fire "fighting" compared to the East side. In the Washington Wildfire Protection Strategic Plan presentation, the East side is very aware of the fire situation and half of the responders feel somewhat prepared for wildfires.[240] The same cannot be said about the West side. As more people move into the WUI from the cities, the resistance to living sustainably with fire increases.[241] Setting back potential fuel treatments mitigation tactics. Even so, the relationship with fire must be mended to have natural forests since natural forests require fire.

Proper education can restore the human-fire connection. As mentioned preciously in regard to the decline of human-made wildfires in WA, education absolutely works. The United States Forest Service, Firewise USA, National Fire Protection Association, etc. all provide an abundance of teaching material about fire ecology and prevention to use in public schools and communities. There is not a lack of resources to initiate edification, there is a lack of funding and

---

238 (*About the Campaign*)
239 (*Benefits of Fire*)
240 (*Washington Wildland Fire Protection Strategic Plan Workshop*)
241 (*Harvey*)

motivation to actively and sufficiently do so.[242] The drawback is that there isn't enough public awareness and recognition of the beneficial role of fire. A large number of citizens and environmentalists distrust the notion of fuel treatments.[243] Nevertheless, recently, mass media has begun to confer about wildfires and its impacts.

Climate Change in Connection to Wildfires

How the warming climate and years of fire suppression has increased lightning-started wildfire frequency.

Climate change does not directly cause wildfires, it is a risk multiplier. Fire suppression and climate change has allowed dry fuel-like vegetation to accumulate, making it easier for any ignited fire to spread rapidly and severely. An ignition source that causes some of the most damage is lightning. According to Professor Jaffe from the University of Washington, lightning causes about 20% of fires and burns 55% of the area.[244] With the increase in temperature, the length of the fire season has extended by 80 days in some areas of the Western region.[245] Coupled with flora overgrowth from fire suppression, there is a lot of arid vegetation ready to light up with a strike of lightning. In addition, global warming has resulted in less summer precipitation and longer droughts, making the vegetation even drier.[246]

Going into more detail, the average year in the Northwestern region is 1.54ºF warmer than during the first half of the 21st century.[247] This increase in temperature results in earlier snowpack melt of which has decreased 20-25% in the Washington Cascades between the 1950s and 2006.[248] Since the snowpack melts quicker in the spring due to the abnormal rise in temperature, there is an earlier surge in water availability and grassland vegetation growth. This may seem great, until the water dries out before summer, making the influx of vegetation drier than usual. All of this combined with the altered precipitation patterns and droughts creates the ideal conditions for a wildfire to sprout.

A misconception to debunk is that climate change does not affect wind patterns and speed, nor does it affect lightning patterns and frequency.[249] There is no evidence that suggests otherwise. The reason huge wildfires happen, like the Camp Fire, is because the conditions

---

[242] (*Raymond*)
[243] (*Raymond*)
[244] (*Jaffe)*
[245] (Jaffe et al., 30)
[246] (Jaffe et al., 31)
[247] (*Raymond*)
[248] (*Raymond*)
[249] (*Raymond*)

permit it to happen. Strong winds, like the Santa Ana winds, though not affected by climate change, do make the spread of fire easier and faster, resulting in these ginormous wildfires. Lightning, more prominently dry lighting (lightning that strikes with no precipitation), ignites the plethora of dry vegetation, which then ignites everything around it. These perfect wildfire conditions will continue to persist, even get worse, if no action is taken to lessen the damage of climate change. "There will be longer fire seasons, greater difficulty in controlling and suppressing the fires, and more days with extreme fire danger." [250]According to Dr. Raymond, forest acres burned will multiply four times by the 2040s, this is concerning as 197 fires since 2000 have consumed more than 100,000 acres each, and 13 consumed over 500,000 acres each.[251]

Since climate change is human induced, it can be solved through human actions. Each state in the Western region has proposed and are executing climate change action plans, all reducing greenhouse gas emissions. Washington state's main contributor to greenhouse gases is vehicle emissions.[252] On March 25th, 2020, the governor signed the Zero Emissions Vehicle (ZEV) standard which "requires automakers to deliver a certain number of zero emission vehicles each year, and earn credits based on the number of vehicles produced and delivered for sale."[253] Oregon state is prioritizing fully switching from coal to clean energy by 2030 and hopes to increase renewable energy to 50% by 2040.[254] As for California, since it is a large state, the government made policies to reduce greenhouse gas emissions 40% below 1990 levels by "increasing the use of renewable energy, sequestering carbon in lands, and reducing the petroleum used in the vehicle sector."[255]

Figure 5 August Complex fire (Berger)

Conclusion

The year 2020 was the worst for wildfires in West Coast recorded history. More than 5 million acres burned in California, Washington, and Oregon in the 18,000 detected fires.[256] In

---

[250] (*Raymond*)
[251] (*Raymond*); (Wildfire Statistics)
[252] (*Reducing greenhouse gases*)
[253] (*Reducing greenhouse gases*)
[254] (*Energy and Climate Change*)
[255] (*Climate Action Programs*)
[256] (Migliozzi et al.)

each state, most, if not all, of the fires were sourced from downed power lines, human actions, and lightning. In Washington, 47 fires were ignited by power lines that converged with other fires to create the Babb-Malden, Manning, and Colfax fires, burning 634,000 acres of land.[257] In Oregon, the Riverside Fire consumed 138,000 acres after being intentionally ignited by a human.[258] Lastly, California saw its worst fire in history with the August Complex fire. 1,032,648 acres were burned due to ignition from multiple lightning strikes.[259]

These events and the factors discussed in this report support several essential conclusions:

- Evidence to date suggests that companies in charge of key infrastructure, homeowners in the WUI, and private individuals in the greater region, all have yet to fully adjust their actions to match the large-scale increase in wildfire risk that now faces West Coast populations, forests, and wildlife.
- Even if the rate of ignition from humans was to remain relatively unchanged, the growing impacts related to climate change, such as extreme temperatures, drying conditions, and extended fire seasons, will inevitably result in ever-higher wildfire risk.
- With continued rapid development of the WUI, the combined human-climate risk is constantly present and well-supported and consistent measures must continue to reduce and reverse risk-enhancing actions. This also highlights the importance of raising public and corporate awareness—changing attitudes as well as behavior.

---

[257] (Bernton)

[258] (*Riverside Fire*)

[259] (*August Complex*)

Works Cited

"About the Campaign." *Smokey Bear*, smokeybear.com/en/smokeys-history/about-the-campaign.

Ahrens, Marty. National Fire Protection Association, 2020, *Firework Fires and Injuries*, www.nfpa.org/News-and-Research/Data-research-and-tools/US-Fire-Problem/Fireworks-fires-and-injures#:~:text=Brush%2C%20grass%2C%20or%20forest%20fires,of%20the%20fire%20property%20damage.

"August Complex." *InciWeb the Incident Information System*, USDA Forest Service, 3 Dec. 2020, inciweb.nwcg.gov/incident/6983/.

Baker, David R. "Underground Power Lines Don't Cause Wildfires. But They're Really Expensive." *San Francisco Chronicle*, San Francisco Chronicle, 21 Oct. 2017, www.sfchronicle.com/bayarea/article/Underground-power-lines-don-t-cause-wildfires-12295031.php.

Balaraman, Kavya. "PG&E Failed to Properly Inspect Tower That Caused Camp Fire: CPUC Safety Investigators." *Utility Dive*, 4 Dec. 2019, www.utilitydive.com/news/pge-failed-to-properly-inspect-tower-that-caused-camp-fire-cpuc-safety-in/568407/.

"Benefits of Fire." *Smokey Bear*, smokeybear.com/en/about-wildland-fire/benefits-of-fire.

Bernton, Hal. "'When the Sparks Just Flew': How Power Lines Ignited Dozens of Washington State Fires during Fierce Labor Day Winds." *The Seattle Times*, The Seattle Times Company, 16 Nov. 2020, www.seattletimes.com/seattle-news/environment/when-the-sparks-just-flew-how-power-lines-ignited-dozens-of-washington-state-fires-during-fierce-labor-day-winds/#:~:text=Labor%20Day%20week%20fires%20in%20Washington%20state&text=The%20fires%20caused%20by%20power,283%20homes%20that%20were%20destroyed.

Boston Consulting Group, 2020, *Reducing Utility-Related Wildfire Risk*, www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/About_Us/Organization/Divisions/WSD/Final_Report_WildfireMitigationStrategy_WSD.pdf.

"Burn Restrictions." *Washington State Department of Natural Resources*, www.dnr.wa.gov/burn-restrictions.

California Public Utilities Commission. *PG&E Kern Division Electric Audit*. Retrieved from https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Safety/Electric_Safety_and_Reliability/Reports_and_Audits/Electric_Facilities/EA2010-028.pdf

"Climate Action Programs." *California Environmental Protection Agency*, calepa.ca.gov/climate/.

Eavis, Peter, and Ivan Penn. “California Says PG&E Power Lines Caused Camp Fire That Killed 85.” *The New York Times*, The New York Times, 15 May 2019, www.nytimes.com/2019/05/15/business/pge-fire.html.

Eavis, Peter. “PG&E Says It Probably Caused the Fire That Destroyed Paradise, Calif.” *The New York Times*, The New York Times, 28 Feb. 2019, www.nytimes.com/2019/02/28/business/energy-environment/pge-camp-fire.html.

“Electric Facilities Safety Audit Reports Archive.” *California Public Utilities Commission*, www.cpuc.ca.gov/General.aspx?id=7864.

“Electricity Explained How Electricity Is Delivered to Consumers.” *U.S. Energy Information Administration*, U.S. Energy Information Administration, 22 Oct. 2020, www.eia.gov/energyexplained/electricity/delivery-to-consumers.php.

“Energy and Climate Change.” *State of Oregon: Policy Offices*, www.oregon.gov/gov/policy/Pages/energy_climatechange.aspx.

“Fire in Paradise (full film) | FRONTLINE.” *YouTube*. Uploaded by FRONTLINE PBS | Official, 29 Oct. 2019, https://www.youtube.com/watch?v=F3OX1PR2SCM

“Fireworks Prohibited on Public Lands.” *Mt. Baker-Snoqualmie National Forest*, United States Department of Agriculture Forest Service, www.fs.usda.gov/detail/mbs/news-events/?cid=FSEPRD641146#:~:text=Fireworks%20prohibited%20on%20public%20lands&text=Violators%20are%20subject%20to%20a,held%20liable%20for%20suppression%20costs.

Harvey, Brian. “Wildfires and Climate Change: Pacific Northwest.” JSIS 495, 29 Jan. 2021, University of Washington – Seattle. Lecture.

“How Do Power Lines Cause Wildfires?” *Texas Wildfire Mitigation Project*, Texas A&M Forest Service, 2014, wildfiremitigation.tees.tamus.edu/faqs/how-power-lines-cause-wildfires.

“Inspection and Maintenance Standards*.” California Public Utilities Commission, www.cpuc.ca.gov/General.aspx?id=7719.*

Jaffe, Daniel A, et al. “Wildfire and Prescribed Burning Impacts on Air Quality in the United States.” *Journal of the Air & Waste Management Association (1995)*, vol. 70, no. 6, 2020, pp. 583–615.

Jaffe, Daniel A. “Smoke: The Next Frontier!” JSIS 495, 20 Jan. 2021, University of Washington – Seattle. Lecture.

McFall-Johnsen, Morgan. “Over 1,500 California Fires in the Past 6 Years - Including the Deadliest Ever - Were Caused by One Company: PG&E. Here's What It Could Have Done but Didn't.” *Business Insider*, Business Insider, 3 Nov. 2019, www.businessinsider.com/pge-caused-california-wildfires-safety-

measures-2019-10#:~:text=Pacific%20Gas%20%26%20Electric%20Co.,over%20safety%20measures%20for%20decades.

Migliozzi, Blacki, et al. “Record Wildfires on the West Coast Are Capping a Disastrous Decade.” *The New York Times*, The New York Times, 24 Sept. 2020, www.nytimes.com/interactive/2020/09/24/climate/fires-worst-year-california-oregon-washington.html.

“ORS 161.625[1] Fines for Felonies.” *Oregonlaws.org*, www.oregonlaws.org/ors/161.625.

“Penal Code Section 451.” *California Legislative Information*, leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?sectionNum=451.&lawCode=PEN.

Raymond, Crystal. “Climate Change and Wildfire Hazard in the Pacific Northwest.” JSIS 495, 26 Feb. 2021, University of Washington – Seattle. Lecture.

“Reducing Greenhouse Gases.” *Washington State Department of Ecology*, ecology.wa.gov/Air-Climate/Climate-change/Greenhouse-gases/Reducing-greenhouse-gases.

“Riverside Fire.” *InciWeb the Incident Information System*, USDA Forest Service, 29 Oct. 2020, inciweb.nwcg.gov/incident/7174/.

“RCW 9A.48.020: Arson in the First Degree.” *Washington State Legislature*, app.leg.wa.gov/RCW/default.aspx?cite=9A.48.020.

United States, Congress, California Legislative Information. *Assembly Bill No. 1054*, 7 Dec. 2019. California Legislative Information.

“U.S. Electric System Is Made up of Interconnections and Balancing Authorities.” *U.S. Energy Information Administration*, U.S. Energy Information Administration, 20 July 2016, www.eia.gov/todayinenergy/detail.php?id=27152.

United States, Safety and Enforcement Division. *Appendix A SED Incident Investigation Report for 2018 Camp Fire with Attachments*, California Public Utilities Commission, 8 Nov. 2019. file:///C:/Users/steph/Downloads/I1906015%20Appendix%20A%20SED%20Camp%20Fire%20Investigation%20Report%20REDACTED%20(2).pdf.

Wamsley, Laurel. “Judge Orders Boy Who Started Oregon Wildfire To Pay $36 Million In Restitution.” *NPR*, NPR, 22 May 2018, www.npr.org/sections/thetwo-way/2018/05/22/613374984/judge-orders-boy-who-started-oregon-wildfire-to-pay-36-million-in-restitution.

Washington State Wildland Fire Protection 10-Year Strategic Plan: Solutions for a Prepared, Safe, Resilient Washington. Second Edition, Washington State Department of Natural Resources, Aug. 2019 https://www.dnr.wa.gov/publications/rp_wildfire_strategic_plan.pdf

Washington State Wildland Fire Protection Strategic Plan: Workshop. Washington State Department of Natural Resources. https://www.dnr.wa.gov/publications/rp_fire_plan_workshop_presentation.pdf.

We're Doing More to Protect against Wildfires. 28 May 2020. https://www.myavista.com/safety/were-doing-more-to-protect-against-wildfires.

Western Interconnection, The Western Electricity Coordinating Council, www.wecc.org/epubs/StateOfTheInterconnection/Pages/Western-Interconnection.aspx.

"Wildfire." *National Fire Protection Association*, www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire.

Wildfire Statistics. Congressional Research Service, 4 Jan. 2021 https://www.fas.org/sgp/crs/misc/IF10244.pdf.

Wildfires, www.cpuc.ca.gov/wildfires/.

Fuel Treatment

Jaynie Trull

Introduction

Selectively reducing the fuel available to a wildfire is a key approach to lowering the risk of such an event to people, wildlife, and forests. While fuel treatment is not a panacea for controlling wildfires, historically it has proven to be successful in many landscapes. There are several different methods that can be used for fuel treatment such as prescribed burns, trimming and thinning and pruning. It is important to consider these in terms of both their advantages and disadvantages, as well as their costs. Overall, fuel treatment is an essential tool for mitigating the growing wildfire threat.

Importance of Fuel Treatment

Fuel treatment is used to prevent wildfires from becoming uncontrolled, high severity events.[260] Fuel reduction, when carried out in the right setting and under the best conditions, has been shown to result in faster recovery and more resilient forests. Fuel treatment is an ongoing process that requires maintenance.[261] However, this upkeep is worth the rewards and is proven to be effective, along with other methods of wildfire suppression, in order to minimize the extent of the damage. By the time that suppression is needed, it is safe to assume that the wildfire is already out of control. In foregoing fuel treatment, big risks are being taken which put the survival of populations, wildlife and infrastructure in jeopardy.

Prescribed Burns

Prescribed burning is the method of setting fire intentionally to an area with an overabundance of fuel. It may be carried out near a developing or inhabited area in the wildland-urban interface (WUI), or in an uninhabited section of forest well away from development. The key aims are to reduce the fuel load in order to lower the chances of a major high-severity fire that would seriously damage the forest ecosystem or threaten human life and property.

However, while the method has been successful in many cases, it has also been resisted by some local populations. Reasons include concerns over the ability of wildfire smoke to become a hazard to people in surrounding communities and the possibility that a prescribed burn

---

[260] Camille Stevens-Rumann, “Pre-Wildfire Fuel Reduction Treatments Result in More Resilient Forest Structure a Decade after Wildfire.” (International Journal of Wildland Fire: CSIRO, 2013), 2.

[261] Ibid.

might not. Such concerns can sometimes be allayed by efforts to raise understanding of the specific burn plan and why it is needed. In all cases, however, it is strongly recommended that an integral part of any prescribed burn near the WUI is awareness and support from the local community.

Other factors that determine the decision to begin or postpone a prescribed burn have to do with weather. In the summer-time**,** the fuel becomes too dry and to attempt a prescribed burn is inherently dangerous as it can spread at a faster, uncontrollable rate. As for the winter-time, the fuel becomes too waterlogged and will not ignite a fire.[262] Due to the temporality of these factors, there is a limited time frame as to when this method of prescribed burns can successfully occur specifically during the spring or fall. For example, in the figure below it shows that in 2018 the Western region of the United States, which has colder weather than the Southeast region, had the most area burned by wildfires. However, this region was also receiving the least amount of prescribed burns in the country. With that said, the relative lack of prescribed burns in the western region may be a part of what triggers such expansive wildfires in comparison to other regions within the U.S.

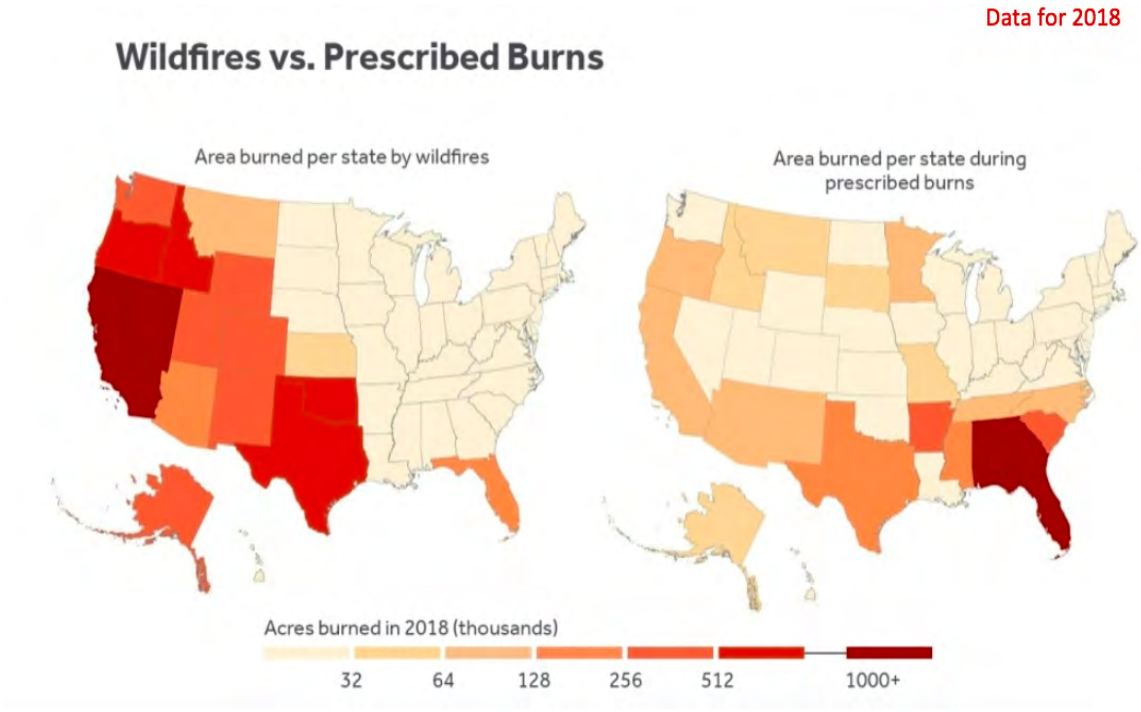


Figure 1: *Area burned by wildfires in the United States vs. Area burned in the United States by prescribed burns (Climate Central))*

[262] Dan Jaffe, "Smoke: The Next Frontier!", 2021.

Advantages

A significant advantage to prescribed fires is that they make suppression of wildfires a lot more manageable, resulting in less area being burned.[263] Prescribed burns are done much quicker than other methods and are less costly, as well as possess the capability to create a better environment for native plants and animals in the long term by reducing needless vegetation and leaving more resources available for them to use.

Disadvantages

It is also important to consider the disadvantages of doing prescribed burns, such as the health risks posed by smoke, which grow as plumes, migrate from the fire from which they were emitted. Since the long-term effects of inhaling such toxic fumes requires further research, the smoke from prescribed burns may threaten populations to an extent which remains unknown.[264]Alongside immediate fire suppression efforts, resources such as trained personnel, and equipment may be constrained in order to protect WUI communities from the encroachment of wildfires.

Trimming and Thinning

Another method in which fuel treatment is used as a way to reduce risk mitigations is through trimming. This entails the usage of machinery or other equipment to remove heavy growing vegetation and brush from the landscape, thereby reducing the tinder available to wildfires. It also involves thinning of branches and the canopy, which are crucial beginning points for wildfires. Thinning is the method of removal of trees to promote healthy growth of other trees and making more natural resources available.

Advantages

A significant advantage of thinning is how it does not require particular weather conditions and it is not constrained by the seasons, unlike prescribed burns. Thinning is a preventative measure that is particularly advantageous for communities that neighbor wildlands, and are vulnerable to the immediate threat wildfires pose. There are less health hazards that come along with thinning than some of the other methods as it doesn't require combustion, which releases toxic fumes.

---

[263] Quinton, Sophie, "To Control Forest FIRES, Western States Light More of Their Own.", Stateline. 16 May 2019.
[264] Ibid.

Disadvantages

One concern that needs to be considered is the prospect of time. Trimming can take more time to help reduce the risks of wildfires as opposed to that of prescribed burns.[265] Thinning is not nearly effective on its own, and works better in combination with other methods, such as prescribed burns. Another disadvantage to this fuel treatment method is that it relies on constant upkeep in order to effectively limit fuels available to wildfires, and the severity of wildfires.[266] This high level of maintenance can be problematic when faced with a shortage of personnel.

Pruning

Pruning is the method of cutting unnecessary branches from trees so that they are not hanging to close the ground in order to limit the spread of wildfires. Typically**,** the limbs removed from the tree do not grow back, whereas trimming is used to promote healthy growth.[267] Pruning when used consistently increases the lifespan of trees as well as promotes them to have a healthy structure which decreases the chance of a wildfire spreading. There are two common methods to pruning, vertical spacing and horizontal spacing.[268] Vertical spacing is used by removing growth and vegetation that are growing or hanging close to the ground, generally about to 6 feet or higher, while horizontal spacing is removal of branches between the canopies of trees that reside close together. Pruning is frequently done on overgrown forests or where the poor health of trees makes them more susceptible to wildfires spreading. [269]

Advantages

Pruning allows the trees and other plants to grow back healthier which in turn allows said plants to be able to withstand intense wildfires. In addition to restoring the health of forests, pruning also works to collapse the vertical fuel ladder. This ladder refers to the movement of a wildfire from the ground upwards into the canopy, spreading with the help of branches and other growth. This excessive growth is not necessary to the health of the forest, and only assists wildfires in spanning further into neighboring communities, threatening both infrastructure and populations.

---

[265] Stephen Fitzgerald, “Fire FAQs-What Is Forest Fuel, and What Are Fuel Treatments?”. Oregon State University, 1 Jan. 2019.

[266] Ibid.

[267] Care, Vintage Tree. “Tree Pruning for Fire Prevention & Defensible SPACE: VINTAGE Tree Care.” 26 Jan. 2018

[268] Ibid.

[269] Colorado State Forest Service. “Protecting Your Home from Wildfire: Creating Wildfire-Defensible Zones.” Colorado State Forest Service, 11 Dec. 2020

Disadvantages

If done incorrectly, pruning can significantly damage the health of a tree thus making it more susceptible to the onslaught of wildfires. [270]With that said, pruning is only effective when branches that are higher than ten feet off the ground are removed, otherwise forests are weakened. Beyond this technicality, pruning is time consuming and therefore impractical when considering larger forests.

Other Approaches to Fuel Treatment

In addition to the fuel treatments mentioned above, another preventive approach is breaking the spatial connectivity of fuel hazards in high-risk areas for wildfires. In doing so, this wildfires from being able to vastly spread across a larger area and support suppression efforts. This would protect property as well as protect neighboring communities and ecosystems.[271] In the article, "An Optimisation Approach for Fuel Treatment Planning to Break the Connectivity of High-Risk Regions", the authors discuss a treatment schedule that acknowledges other locations of treatment, as well as the relationships between the location selected for treatment; as research shows it is relevant to consider spatial arrangement when performing fuel treatments. With this method of using spatial arrangement it is taking into account factors such as distance and vegetation type to then decide what other physical method of fuel treatment to proceed with. [272]In the same article, the authors state, "This multi-period model tracks the age of each vegetation type and determines the optimal time and locations to conduct fuel treatments. For example, some plants, such as blackberry bushes which tend to regrow fairly well after a fire, so pruning and thinning as opposed to a prescribed burn is a better approach where the quantity is high. Another approach that could double as a supplement to fuel treatment is being able to correctly identify where and when a wildfire can occur.[273] The article, "Challenges and Approaches in Planning Fuel Treatments across Fire-Excluded Forested Landscapes" talks about the identification of a "problem" fire, which has great potential to affect human as well as natural resources; Many times, this was a wildfire which happened to prove suppressive methods unsuccessful given the conditions of the weather. This preventive measure alongside physical actions of fuel treatment such as thinning for example, could help improve suppressive methods and potentially stop a wildfire from occurring at all.

---

[270] Ibid.

[271] Ramya Rachmawati,, et al. "An Optimisation Approach for Fuel Treatment Planning to Break the Connectivity of High-Risk Regions." 2016.

[272] Ibid.

[273] Brandon M Collins,, et al. "Challenges and Approaches in Planning Fuel Treatments across Fire-Excluded Forested Landscapes." Journal of Forestry, 29. Jan 2010.

Costs and Funding

Another factor that goes into the planning of fuel treatment is that of costs and funding. Methods of fuel treatment are costly and have to be regulated.[274] In more recent years, in the Western region of the United States, suppression costs of wildfires have increased with the overwhelmingly rapid growth of the Wildland-Urban Interface (WUI) being developed in areas that are prone to wildfires. These areas need funding in order to construct defensible mechanisms and use fuel treatments to lower the risks of potential wildfires.[275] The cost of wildfires is expected to be 2 to 30 times that of suppression costs, which is numerically higher than what the public is informed about. With adequate funding for preventive measures such as fuel treatments, the number could be significantly lower.

In addition to financial costs, there are opportunity costs. For example, in planning for a prescribed burn, it is important to consider the risks of smoke becoming a hazard to public health.[276] In 2018 alone, Colorado spent $40 million to suppress and put out wildfires and just $7 million on efforts that would reduce the risk of the fire severity from the beginning.[277] The article, "Modeling Fuel Treatment Impacts on Fire Suppression Cost Savings: A review.", discusses this idea of using fuel treatments to lessen the expenditure of suppression because there is evidence that they can increase firefighter safety, as well as success in suppressing wildfires Essentially, they are claiming that there is evidence which shows the benefits of fuel treatment, in terms of lowering the cost of fire suppression. However, there cannot be more funding for fuel treatment processes because there is no data to show the difference in suppression on land that has been treated versus untreated.[278]

The point to be made here is that the Western region of the United States is not adopting the best management practices to prevent wildfires and allowing for more potential risks of disasters in the future. With evidence and research to show that preventive measures can aid in a mass amount of risk and damage reduction caused by wildfires, there is little to no reason why the correct funding and actions should not be taken. Figure 2 below will give more of a visual of the deficit between the funding for fuel treatment versus wildfire suppression. Additionally, this graph depicts how the United States is not funding preventive measures nearly enough.

---

274 Jason Kreitler, Matthew P. Thompson, Nicole M. Vaillant, Todd J. Hawbaker (2019) Cost-effective fuel treatment planning: a theoretical justification and case study. International Journal of Wildland Fire 29, 42-56.

275 Lisa, Dale,."The True Cost of Wildfire in the Western U.S." Western Forestry Leadership Coalition. April 2009.

276 Quinton, Sophie, "To Control Forest FIRES, Western States Light More of Their Own.", Stateline. 16 May 2019.

277 Anderson M. Thompson, N. 2015. "Modeling Fuel Treatment Impacts on Fire Suppression Cost Savings: A review." Calif Agr 69(3):164-170.

278 Crystal A., Kolden, "We're Not Doing Enough Prescribed Fire in the Western United States to Mitigate Wildfire Risk." Fire 2.2 (2019): 30. Crossref. Web.

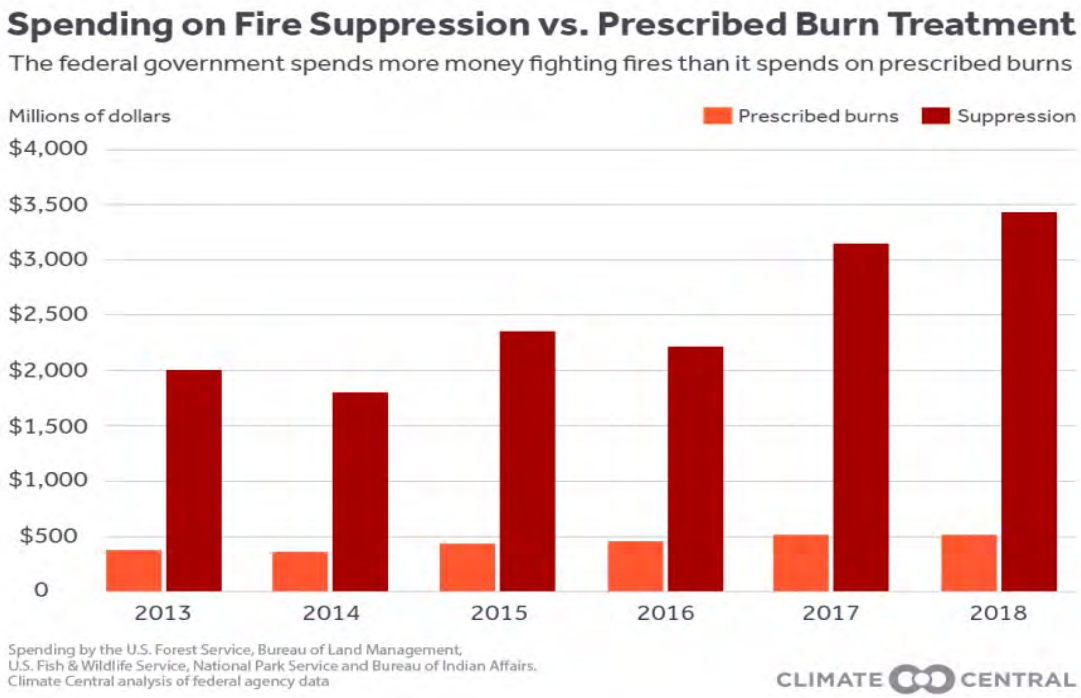


Figure 2: *Funds spent on Fire Suppression vs. Prescribed Burns (Climate Central)*

Comparison of Fuel Treatment Methods

While there are different methods to use for fuel treatment, not every method will be able to work as efficiently as others. There are many different factors that impact the decisions as to which method of fuel treatment should be used such as the weather, climate, and the time of year of the area that is needing to be treated. Additionally, most of these fuel treatment methods can be used in conjunction with one another. For example, trimming and pruning are better methods to use specifically in the western region of the US as the time frame to do prescribed burns is limited in this area due to the amount of precipitation and wetness. Although some communities can be opposed to trimming and pruning because if done incorrectly they can damage the trees in the forest from being able to grow healthy and repair themselves. In places like Florida and the southeastern region of the US where it stays relatively dry during the fall and winter, but at cold enough temperatures from keeping the forests from being too dried out, a prescribed burn may be the best solution in order to prevent wildfires. Understanding the conditions unique to a particular region that are suitable for either one of or a combination of these fuel treatment methods is necessary for policymakers.

Conclusion

In conclusion, fuel treatment as a means to reduce the risks of wildfires spreading and the damage that comes from them is completely necessary, especially in the western region of the United States. Using the methods of fuel treatment mentioned above can contribute to saving

human lives, protecting property and wildlife at the hands of severe wildfires. With these fuel treatments, it is important to note these main takeaways:

- Involving the local community at some level is important
- Consistency of treatments is key
- Adequate funding is needed if prescribed burns are to be more widely used to reduce wildfire risk
- Two or more fuel treatment methods may need to be considered in some cases

Works Cited

Care, Vintage Tree. “Tree Pruning for Fire Prevention & Defensible SPACE: VINTAGE Tree Care.” 26 Jan. 2018, www.vintagetreecare.com/fire-prevention-tree-pruning

Colorado State Forest Service. “Protecting Your Home from Wildfire: Creating Wildfire-Defensible Zones.” Colorado State Forest Service, 11 Dec. 2020, csfs.colostate.edu/.

Collins, Brandon M., et al. “Challenges and Approaches in Planning Fuel Treatments across Fire-Excluded Forested Landscapes.” Journal of Forestry , Jan. 2010, www.fs.fed.us/psw/publications/4202/psw_2010_collins001.pdf.

Dale, Lisa. “The True Cost of Wildfire in the Western U.S.” April 2009. Western Forestry Leadership Coalition. https://www.blm.gov/or/districts/roseburg/plans/collab_forestry/files/TrueCostOfWilfire.pdf

Fitzgerald, Stephen A, et al. “Fire FAQs-What Is Forest Fuel, and What Are Fuel Treatments?” Fire FAQs-What Is Forest Fuel, and What Are Fuel Treatments? | OSU Extension Catalog | Oregon State University, 1 Jan. 2019, catalog.extension.oregonstate.edu/em9230/html

Jaffe, Dan. “Smoke: The Next Frontier!”. Jan 20, 2021.

Kolden, Crystal A. “We’re Not Doing Enough Prescribed Fire in the Western United States to Mitigate Wildfire Risk.” *Fire* 2.2 (2019): 30. *Crossref*. Web.

Kreitler Jason, Thompson Matthew P., Vaillant Nicole M., Hawbaker Todd J. (2019) Cost-effective fuel treatment planning: a theoretical justification and case study. International Journal of Wildland Fire 29, 42-56.

Quinton, Sophie. To Control Forest FIRES, Western States Light More of Their Own. 16 May 2019, www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2019/05/16/to-control-forest-fires-western-states-light-more-of-their-own.

Rachmawati, Ramya, et al. “An Optimisation Approach for Fuel Treatment Planning to Break the Connectivity of High-Risk Regions.” Forest Ecology and Management, vol. 368, 2016.

Stevens-Rumann, Camille, et al. “Pre-Wildfire Fuel Reduction Treatments Result in More Resilient Forest Structure a Decade after Wildfire.” International Journal of Wildland

Fire, vol. 22, no. 8, 2013.

"THE BURNING SOLUTION: Prescribed Burns Unevenly Applied Across U.S." Climate Central, 29 May 2019,
https://www.climatecentral.org/news/report-the-burning-solution-prescribed-burns-unevenly-applied-across-us

Thompson M, Anderson N. 2015. "Modeling Fuel Treatment Impacts on Fire Suppression Cost Savings: A review." Calif Agr 69(3):164-170.

Preventive measures to fight wildfires in the Western region

JC Ye

Introduction

Wildfire has been a vital process in nature since time immemorial, but decades of fire suppression have significantly restricted this process and created a large overabundance of fuel, particularly in the western U.S.. Many coniferous forests have a natural regime of low-intensity wildfires, which plays an essential role in decreasing dangerous fuels and restoring forest ecology. For nearly 400 million years, wildfires have been a necessary natural process that have positively affected the surface of our planet. Many animals and plants in the Western region of the US have evolved to cope with fire to the point that some plants require it to thrive. A wide range of old-growth woodlands in the Pacific Northwest were born because of massive and severe wildfires thousands of years ago. In contrast to past centuries, the current wildfire problem causes many issues. The history of fire suppression has transformed the nature of wildfires and significantly increased the threat posed to neighboring communities. Gradually, wildfires appear to be becoming a greater environmental disaster causing tremendous risks for public health and safety. This evolution of the wildfire problem needs to be halted by more preventive measures.

Not only is the post fire weather drier and hotter than it was centuries ago, but the natural fire regimes have also been expanded over an extended period of time, so the wildfire situation becomes harder to recover appropriately. Unlike the historic wildfires that thinned out plants and left thriving fields in their wake, the uncontrollable nature of today's wildfires emits toxic smoke across entire regions and incurs costly damages to communities, especially WUI inhabitants. Therefore, the current issue around the fire management is based on an urgent need to develop and transform western regions including California, Oregon, and Washington states' firefighting programs: to create efficient fire-adapted communities, restore damaged landscapes, respond cautiously and effectively to wildfire, and gain financial support for recently updated initiatives.

Current Approaches to Managing Wildfires

The current programs require transformation in terms of funding, resources, research, etc.

The experts warn that modern programs for wildfire management are no longer efficient. Two climate reporters Plumer and Schwartz state that "the first step is to acknowledge that fire is

inevitable, and we have to learn to live with it". [279]In the 21st century, American populations are expanding into fire-prone regions because of how affordable it is. As long as these communities are resistant towards limiting further development, the methods of wildfire management must evolve to better protect the WUI and those inhabiting it. In the past, most programs were only focused on the immediate suppression of wildfires rather than letting them burn at low and controlled levels. To meet the needs of these environmentally vulnerable communities, wildfire management methods have started to allow smaller, controlled burns. This is because such an adverse approach to wildfires has left woods with large quantities of fuel which significantly contribute to the size and threat posed by wildfires. Current wildfire management methods are focused on using prescribed fires as treatment for the overabundance of vegetation that intensifies wildfires. Another popular program involves the enforcement of specific regulations on buildings constructed in fire-prone districts.

Unfortunately, all of the mentioned programs are still developing too slowly. The current programs of the wildfire management incorporated by Western states require transformations, especially in terms of funding, resources, research, and personnel.

Wildfire Management Programs by the State of California

California has created multiple programs to prevent wildfires.

California's firefighting communities have created special programs to resist fires to prevent and reduce wildfire hazards. First, the Fire Protection Program (FPP) is considered a key priority for California. Hence, CAL FIRE's fire personnel aim to respond to all types of emergencies, including "wildfires, residential/commercial structure fires, automobile accidents, heart attacks, drownings, lost hikers, hazardous material spills on highways, train wrecks, floods, earthquakes - the list is endless".[280] Second, Resource Management is also an essential program that maintains the sustainability of natural resources such as land, water, plants, especially those related to landowners and forests. State and federal forestry assistance initiatives for landowners' present research and educational outreach to the public. Third, the Office of the State Fire Marshal (OSFM) also helps manage the ongoing wildfire crisis in California. According to the official website of the state of California, the OSFM " supports the mission of CAL FIRE by focusing on fire prevention through a wide variety of fire safety responsibilities including regulating buildings in which people live, congregate, or are confined".[281] Fourth, the Fire and

---

[279] Plumer, *These Changes Are Needed Amid Worsening Wildfires, Experts Say*,2020

[280] Fire.Ca.Gov, *Welcome to CAL Fire Programs*, 2021

[281] ibid

Resource Assessment Program (FRAP) concentrates on free, unlimited access to extensive technical and public data for statewide fire warnings. At the same time, FRAP also focuses on fire dangers, abnormal environmental indicators, and forest-related climate variations. Fifth, the Californian government plans to develop and finance policies that serve the public interest in environmentally, ecologically, and culturally sustainable woodlands supervision. Finally, the Communication Program provides information and education about wildfires to people of all ages while the Equal Employment Program ensures equal employment opportunity for all workers and volunteers that support firefighting initiatives. All of these play an essential role in preventing wildfires in California.

Results & Impacts of Management Programs by the State of California

High level of effectiveness and a significant set of resources are implemented.

California implements a wide range of firefighting programs that are associated with a high level of effectiveness. For instance, the FRP calls for the protection of over 30 million acres of California's woodlands, whereas forest management on eight state forests is provided by state and national tree-planting assistance programs. California's Communication Program positively affects fire safety awareness because it freely educates people through the worldwide web, printed materials, and media. Furthermore, the Communication Program is divided into several blocks of information such as fire safety inside and outside the home, holiday fire safety, and defensible space management. The defensible space will reduce the risk that fire will spread from one area to another, especially in the WUI area. Concerning the OSFM, this program established "a fire-safe environment for the people of California, which serves as a foundation for local agencies to build on as they strive to meet their specific goals". [282]

Given the importance of wildfire preparedness, California has mobilized a significant set of resources consisting not only of committed professionals but also technologies, including drones, jet aircraft, fire maps, and evacuation phone apps for effective fire management. [283]Despite funding cuts under President Trump, California continues to receive wildfire aid to implement specific programs by appealing directly to the White House and using supplying aid from organizations such as the California Fire Foundation.

---

[282] Osfm.Fire.Ca.Gov, *Office of the State Fire Marshal*, 2021

[283] Helvarg, *Fireball-Dropping Drones and the New Technology Helping Fight Fires,* 2020

Critical needs of current fire management in California

California needs to rethink the fire management policies while requiring more appropriate financial support.

Before the 20th century, wildfires have helped conduct the evolution of California's plant life and ecological areas. Researchers emphasize that before settlers populated the region in the 1800s, “about 5 to 12% of the land that now makes up the Golden State caught fire each year… the most destructive year in modern history". [284] However, the wildlands have dramatically changed in the 21st century due to the accumulation of fuels from decades of suppressing the natural fire regime as populations within the region multiplied and integration within the wildlands became deeper. In contrast to the historic fires, wildfires pose a health and safety risk to communities both near and far, as smoke migrates beyond the region from which it was emitted. The flames burning California emphasize the urgency of rethinking fire management policies because rapid climate transformation endangers to make things worse. While California needs more fire to fix its environmental problems, it also requires appropriate financial support because controlled burns appear to be a costly initiative that may negatively affect the state’s budget. To help address the funding issues, state governors should introduce more bills to incentivize the use of controlled burns. It is significant because about 46% of California land is managed by the federal government, according to a 2020 Congressional Research Service report.

Wildfire Management Programs by the State of Oregon

ODF introduced extensive fire protection networks along with technologies to monitor the fire.

The Oregon Department of Forestry has recently revealed its Fire Protection Program, which serves to protect millions of acres of Oregon's forests. This program protects private land as well as state-owned woodlands. According to the official website of Oregon's government, "ODF is also part of an extensive fire protection network that includes landowner resources, contract crews and aircraft, adults in custody crews, and agreements with public agencies across Oregon, the US, and British Columbia". [285] The FRP's principal purpose lies in preventing all fires (even the smallest ones) as quickly as possible with the use of fire suppression. However, such an aggressive approach of fire suppression only worked ideally as the years of suppression now lead to the huge accumulation of fuel loads. The ODF introduced fuel load estimating tools to monitor the amount of the use of fire suppression. In addition to all of the above, most of the lands protected by this governmental initiative are working woodlands; that is why the Fire

---

[284] Sobieszczyk, *California May Need More Fire to Fix Its Wildfire Problem,* 2020

[285] Oregon.Gov, *Oregon Department of Forestry: Fire,* 2021

Protection Program also supports jobs because it provides a wide range of positions for firefighters, guards, etc. There is seasonal recruitment every summer and these seasonal employees serve a critical role in protecting the state from fire during the summer.

Results & Impacts of Management Programs by the State of Oregon

The programs involve more active forest management rather than the continuous action of fire suppression.

Although Oregon's Fire Protection Program has shown multiple advantageous results, its aggressive firefighting approach only hurts the environment in the long run**.** Unfortunately, fire suppression has only a short-term positive impact, whereas its long-term consequences negatively affect the environment. The suppression of natural wildfire leads to thick, overcrowded forests with excessive vegetation. This overgrowth ideally would be tamed by smaller, controlled burns. However, the denial and suppression of the natural fire regime has led to the accumulation of fuels and tinder necessary for wildfires to expand. As a result, the wildlands are subject to more intense and uncontrollable fires that are likely to cause severe damages.

On the contrary, the Fire Protection Program's restoration practices involve active forest management. [286]By implementing more preventative measures such as thinning trees, harvesting dry brush, and controlled burning, ODF managed to not only restore the balance of forests but also reduce the risk of such devastating fires. Ultimately, the amount of large catastrophic fires has significantly decreased because of this efficient tactic. In the recent data from the website of the ODF, the frequency of wildfires statewide annually were way below the 10-year average.

Critical needs of current fire management in Oregon

Oregon is raising the budget on fire prevention while promoting people's structural resilience towards wildfire.

Since the Global Financial Crisis in 2008, Oregon has been reducing its firefighting capacities despite the significant escalations of wildfire activities that have evolved in recent years. As a result, Oregon remains one of the most unprotected states in terms of wildfire resistance. The governor's council of Oregon confirms this vulnerability, stating that "the State must expand the scope of its protection services, adding over 1 million acres to the 16 million acres it already

---

[286] ibid

protects to ensure all lands in Oregon have adequate wildfire protection". [287] Speaking directly about the resources and funds that are needed in a critically low level of security, one should note that Oregon lawmakers more constantly try to increase The ODF's budget not only through a direct request to the Oregon Legislature's Emergency Board, but also via donations. With the help of various foundations, financial resources are increasing every year. In order to maintain and repair resilient landscapes, the state must regularly control its forests by developing different treatments such as controlled burns, thinning, and fuel extraction. Last but not least, it is also essential to enhance structural resilience to wildfire, improve defensible space surrounding edifices, and guarantee adequate access and exit in the case of wildfire events. By implementing the idea of structural resilience to wildfires, People will have a better understanding of the more specific social-ecological context by promoting resilience in human exposure and vulnerability to wildfires and demonstrating the impacts of fires and management of recovering from fire events.

Wildfire Management Programs by the State of Washington

The DNR focuses on several critical programs to protect the land from the wildfires.

The Washington State Department of Natural Resources (DNR) focuses on five critical wildfire management programs including Behind-the-Scenes Support, Pre-Season Training, Coordinated Partners, Initial Attack, and Firefighting Jobs. The first program is associated with resources provided for DNR staff. The Behind-the-Scenes Support Program includes well-equipped camps created for DNR staff's comfortable living. Firefighters are provided with all the necessary living facilities ranging from nutritious food to a quiet place for sleeping after exhausting working shifts. At the same time, the Pre-Season Training Program provides training to thousands of people with cooperating agencies each season. There is specific training for different professionals such as equipment operators, firefighters, or members of the national guard and local fire areas. The program related to the engagement of coordinated partners allows DNR to "call on agency-wide resources, local fire districts and agency partners for aid". [288] Even though human-caused wildfires usually cannot be predicted, lightning storms can be easily forecasted. In this case, DNR Wildfire crews implement an Initial Attack Program, which is processed from the Initial attack dispatch rules combined with a stochastic programming model, in order to respond to the natural disaster as quickly as possible. Lastly, DNR offers a wide variety of positions as it "is always looking for dedicated individuals to help protect

---

[287] Oregon.Gov, *Governor's Council on Wildfire Response,* 2019

[288] Dnr.Wa.Gov, *Fighting Fire,* 2021

Washington's natural resources from wildfire".[289] The ultimate goal is to see that nine out of every ten fires on DNR-protected lands are out before they ever exceed 10 acres.

Results & Impacts of Management Programs by the State of Washington

Washington promotes imperative and tactical adjustments among the fire management agencies.

Due to the Coordinated Partners Program, Washington took a big step forward by promoting imperative and tactical adjustment among different wildland fire management agencies and governmental organizations. This program showed positive results in terms of identifying separate missions, functions, and constraints of fire management agencies. Firefighting Jobs and Behind-the-Scenes Support Program popularize the firefighting industry, simultaneously providing workers with all the necessary equipment and facilities. In this regard, it is logical to assume that these initiatives not only guarantee the qualitative and efficient functioning of firefighting services but also fasten the development of Washington's fire management. Though these programs do not correspond to all current problems related to the wildfire problem, they represent a significant contribution to the development of fire protection and resistance measures in the state of Washington.

Critical Needs of Current Fire Management in Washington

Washington needs to develop more ways to deal with climate change and the balance of the ecosystems.

In Washington, the number of shrub-steppe areas continually decreases. According to researchers, this change in terrain is the result of encroaching wildfires. Flatt argues that the shrub-steppe ecosystem historically covered about one-third of the state but now it only covers “less than half of that is still intact".[290] This region may be described as a threatened ecosystem because the invasion of cheatgrass is fueling larger and more frequent fires that are out-competing grass species that possess native components of the steppe ecosystem. Therefore wildfire management must concentrate on slowing the effects of climate change and reversing decades of fire suppression which destroyed the ecological balance of forests. These are considered to be the most critical factors that increase the range and frequency of wildfires. Additionally, Tip Hudson, a livestock expert at Washington State University, proposes to "create healthy plant communities that are both resistant to fire and resilient to fire, instead of trying to

---

[289] ibid

[290] Flatt, *Scientists Say WA Wildfire Management Must Go Beyond Forests,* 2020

fix a plant community after a really hot fire does a lot of damage".[291] Washington needs to develop a wide range of new anti-climate change initiatives in order to keep the ecosystem healthy and prevent wildfires; much more funding and resources is also needed from the federal government for the state to go towards proactive measures.

Conclusion

Since the damage left by wildfires is ever increasing, the Western region of the US needs to develop more fire-adaptive communities and create efficient programs to prevent wildfire. The in-depth analysis of the current wildfire issues showed that western states are actively moving towards strengthening their preventive measures. During the last decades, the western regions managed to develop a comprehensive system of fire management programs that address multiple aspects of the problem, ranging from fire-adapted associations and communication issues to fire suppression and diverse governmental initiatives. Even though these programs have significantly enhanced American wildfire management, there are still some problems to be solved, especially in terms of funding and future-oriented strategies. More proactive measures have to be taken as more communities are getting impacted and larger damages are caused by the expanding of wildfires. Instead of resources being spent on immediate fire suppression, investments should be made in order to restore landscapes and design resilient communities so that wildfires have adequate space to achieve their ecological purpose. Therefore, the preventive measure to wildfire is based on an urgent need to develop and transform western regions:

- create efficient fire-adapted communities
- restore damaged landscapes
- create structural resiliency among people to respond cautiously and effectively to wildfire
- gain more financial support for proactive measures

---

[291] ibid

Works Cited

"Fighting Fire". *Dnr.Wa.Gov*, 2021, https://www.dnr.wa.gov/FightingFire.

Flatt, Courtney. "Scientists Say WA Wildfire Management Must Go Beyond Forests". *Crosscut.Com*, 2020, https://crosscut.com/environment/2020/12/scientists-say-wa-wildfire-management-must-go-beyond-forests.

"Governor's Council on Wildfire Response". *Oregon.Gov*, 2019, https://www.oregon.gov/osp/Docs/GovWildfireCouncilRpt-FinalRecs.pdf.

Helvarg, David. "Fireball-Dropping Drones and the New Technology Helping Fight Fires". *Science*, 2020, https://www.nationalgeographic.com/science/2020/10/fireball-dropping-drones-new-technology-helping-fight-fires/.

"Office of the State Fire Marshal". *Osfm.Fire.Ca.Gov*, 2021, https://osfm.fire.ca.gov/.

"Oregon Department of Forestry: Fire". *Oregon.Gov*, 2021, https://www.oregon.gov/odf/fire/Pages/default.aspx.

Plumer, Brad, and John Schwartz. "These Changes Are Needed Amid Worsening Wildfires, Experts Say". *Nytimes.Com*, 2020, https://www.nytimes.com/2020/09/10/climate/wildfires-climate-policy.html.

Sobieszczyk, Steven. "California May Need More Fire to Fix Its Wildfire Problem". *Pewtrusts.Org*, 2020, https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2020/09/18/california-may-need-more-fire-to-fix-its-wildfire-problem.

"Welcome to CAL FIRE Programs". *Fire.Ca.Gov*, 2021, https://www.fire.ca.gov/programs/.

State of the Art and Limitations

Rachel Demaree

Introduction

When considering fire management, it is imperative to have realistic expectations. No matter how effective fuel treatment, land use, public awareness, and infrastructure are, they each have their own limitations. As wildland fires continue to grow in complexity and severity, understanding what the challenges are for each fire management approach may help to create dynamic, balanced solutions in planning. From understanding the administrative, technical, and environmental sides, federal, local and state governments can tailor their fire management and risk mitigation to their own regions with specific needs.

No single approach is universal, so it is critical to remain flexible with each management technique and to focus on localized approaches as needed. Furthermore, it is of utmost importance to understand the limitations of different approaches to fire management. This chapter will focus on several different approaches and their constraints, including fire management such as prescribed burning, thinning, and mastication. Additionally, this chapter will consider land use approaches such as privately owned land fire resistance alterations and organizational barriers, as well as community-based approaches like Community Wildfire Protection Plans and institutional drawbacks. Another major challenge is public and landowner awareness regarding bureaucratic procedures, social values, and infrastructure maintenance. Each approach has its own issues regarding managerial, administrative, and social issues, such as budget and trained personnel, as well as technical and environmental constraints.

Fuel Treatment Approaches

Fuel treatment methods are much needed but have administrative and environmental limitations.

Limitations of Prescribed Burning

Prescribed burning is a critical aspect of wildfire management, especially going forward. However, it is important to acknowledge that management approaches like prescribed burning are not universal—each method is only part of a more comprehensive set of approaches to be considered on a case-by-case basis.

The limitations of prescribed burning can be identified by the following categories: economic, legal, administrative, technical, and environmental. According to a survey conducted

by the National Forest Service, the most important categories of these are economic and legal.[292] The economic category considers budget, funding, and planning costs, which can be an estimated $195.71 per acre, depending on the type of prescribed fire taking place and on whether the fire is in the Pacific North or Southwest.[293] The total acreage of all national forests in Pacific North and Southwest is 44,497,365, though only 169,075 acres receive prescribed burn treatment annually.[294] Given this, the prescribed burns in this region currently cost the National Forest Service about $3.3 million out of its budget of $5.7 billion.[295] Prioritizing funds for regions that are more prone to wildfires may help with this.

Legal limitations include regulations, especially those on air quality, smoke management, and environmental protection. This is due to health concerns over the potential respiratory impact and environmental laws. Since prescribed burning emits large quantities of smoke, nearby WUI and other communities can be (significantly) affected. Additionally, liability is a major limitation due to the chances of escaped fire occurring, injury, and more.[296] Insurance for prescribed burning can be expensive and is not necessarily widely available.

Public opinion can also prevent or make prescribed burns difficult because the officials granting them are well aware of the expressed dislike of smoke in populated areas. Public officials may be cautious when deciding whether or not to allow a controlled burn due to the respiratory implications to the population nearby.

Legal barriers also affect the technical prospect through the window the burn can take place, depending on state and local laws. This on top of seasonal, climate, and weather limitations, narrows the window for the burn.[297] Because prescribed fires have to take place in the right conditions—not too wet (the fire will not start), not too dry (the fire may be uncontrollable), and not too hot or cold (the same reasons)—it is a major barrier for regions like the deserts of eastern Washington, Oregon, and southern California, and for the rainy western regions of the same states. This means that prescribed burns can only take place in the spring or fall each year, when climate and weather conditions permit. An additional technical difficulty is the terrain in which the prescribed burn is taking place. For example, it is much easier to control a burn on flat terrain than on steep terrain. This could potentially lead to an increase in the cost to perform the prescribed burn or make certain areas impossible. Administrative shortcomings are

---

[292] Cleaves, David A., et al. *Influences on Prescribed Burning Activity and Costs in the National Forest System*. U.S. Dept. of Agriculture, Forest Service, Southern Research Station, 2001, 1.

[293] Ibid, 17.

[294] Ibid, 7.

[295] Ibid, 16.

[296] Cleaves, David A., et al. *Influences on Prescribed Burning Activity and Costs in the National Forest System*. U.S. Dept. of Agriculture, Forest Service, Southern Research Station, 2001, 16.

[297] Ibid, 16.

mostly due to a shortage of trained, qualified personnel to conduct the burns.[298] Without enough qualified people to perform the burns, the amount of area that can be burned is severely limited.

Environmental concerns are also a factor and constraint for prescribed burns. While they can be subtle and mitigated, they still must be acknowledged because it is known to affect plant diversity, deer, shallow water, and air quality. These are important to consider due to environmental laws on the federal, state, and local levels.

A University of Alberta study tested how the chemical composition of shallow groundwater changed before and after prescribed burning in a section of provincial forest. It found substantially increased concentrations of phosphorus and inorganic nitrogen, which can have significant impacts depending on whether rainfall pushes the chemicals downstream.[299] Increased nitrogen and phosphorus "may lead to increased primary productivity and eutrophication of small lakes," meaning rapid ephemeral growth of plants that may harm wildlife.[300] While the study found that the nitrogen levels declined to pre-fire levels in a span of a few months, it could still have lasting impacts. If the chemicals are pushed downstream, it could lead to algae growths that consume oxygen needed for fish and other wildlife. While this study took place in a region that is outside the scope of this Task Force, it is still worthwhile to consider these implications. Additionally, decay from eutrophication may decrease water quality for larger mammals, such as white-tailed deer, a species that is prominent across the United States, especially in semi-arid rangelands like eastern Washington and Oregon. In 2008, a study published by the Journal of Arid Environments looked at how white-tailed deer interacted with new growth from prescribed burns in Texas. After prescribed burns, researchers expected the deer to eat the new growth, however there was relatively low use from deer due to drought, which left only a brief growth of grass in the autumn.[301] Because of this, employing prescribed burns in semi-arid environments may not be best when considering deer populations and ecosystems as a whole.

Prescribed burns also affect understory vegetation and air quality. In dry coniferous forests like the ponderosa pine forests, understory vegetation makes up most of vascular plant diversity.[302] The Humboldt State University in California performed a study on how native plants adapted to seasonal and interval prescribed burning in northeast Oregon using data from 2002 to 2015. According to the study, native plants are not well adapted to seasonal and interval

---

[298] Ibid, 16.

[299]Orlova, Julia, et al. "Effects of Prescribed Burn on Nutrient and Dissolved Organic Matter Characteristics in Peatland Shallow Groundwater." *Fire (Basel, Switzerland),* vol. 3, no. 3, 2020, 3, 53.

[300] Ibid, 7.

[301] Meek, M.G, et al. "White-Tailed Deer Distribution in Response to Patch Burning on Rangeland." *Journal of Arid Environments*, vol. 72, no. 11, 2008, 2026–2033.

[302] Zald, Harold S. J, et al. "Limited Effects of Long-Term Repeated Season and Interval of Prescribed Burning on Understory Vegetation Compositional Trajectories and Indicator Species in Ponderosa Pine Forests of Northeastern Oregon, USA." Forests, vol. 11, no. 8, 2020, p. 834. <https://doi.org/10.3390/f11080834>.

prescribed burning due to an ephemeral effect of frequent burning.[303] This allows invasive species such as *Bromus tectorum*, better known as cheatgrass, to thrive over time. However, the effects are subtle and have taken place for over a decade and there are no substantial changes.[304] Still, considering the frequency and the type of prescribed burn may help to prevent invasive species from taking over ecosystems while native species die out. Air quality affected by smoke is another drawback of prescribed burning, especially for WUI and wildlife.

Limitations of Thinning

Another method of wildfire management is thinning, which has its own limitations. One of these is the cost. A report from the Oregon Department of Agriculture found that even from selling the fallen trees, the state still lost approximately $100 per acre of trees thinned that were 3 to 5-inch trees. Figure 1 breaks down the cost. This cost (or profit) depends on several factors including tree size, volume harvested, terrain, markets, and unit location.[305] Tree size may increase the value of the merchantable timber, making it sell for a higher price, but it also raises the cost to cut it down. The volume harvested pertains to the amount of merchantable timber that needs to be transported or chipped down and how much equipment to perform the job needs to be moved. Perhaps obvious, the market determines the value of the merchantable timber, which can fluctuate. Because of this, the value of timber can increase or decrease, which impacts how much money is lost or gained from extracting timber from thinning. Because this solution is vulnerable to market forces, it may not always be economically rational. Terrain is a major challenge of thinning because steep terrain is much more difficult to maneuver than flat terrain. More expensive equipment must be used and the expertise required of personnel is much higher. Lastly, unit location considers where the market is and how to transport the merchantable timber to it. Depending on these factors, the cost of thinning may be very high. Additionally, thinning is not a wholly effective solution. Soon after an area is thinned, vegetation begins to grow or regrow. Because of the space in the canopy, the vegetation is able to take up more space and once again become a fire hazard.[306] This means that in order to be effective, thinned areas must be prescribed fire within a year.[307] While the main benefit of thinning is to reduce crown fires, this double-wildfire management technique may prove to be incredibly expensive. Depending on

---

[303] Ibid, 1.

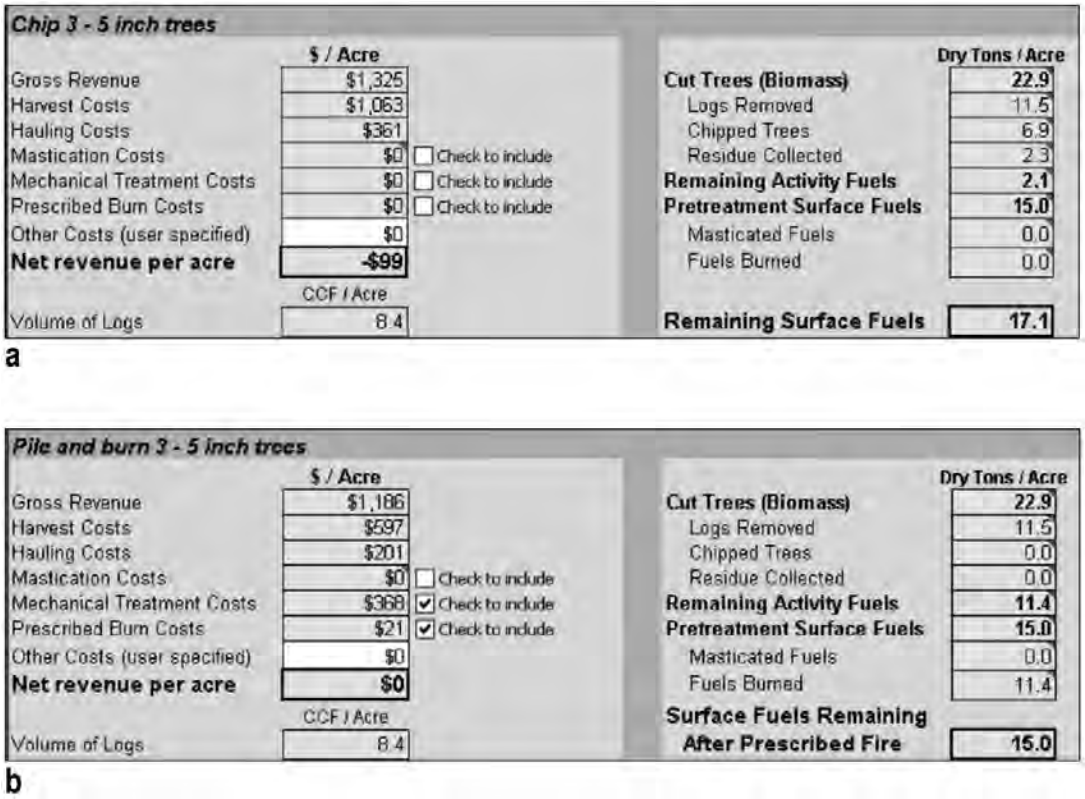
[304] Ibid, 9.

[305]Fight, Roger D, and Barbour, R. James. "Financial analysis of fuel treatments." *Financial Analysis of Fuel Treatments on National Forests in the Western United States*. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, 20.

[306] Brockway, Dale G.; Outcalt, Kenneth W. "Understory vegetation response in longleaf pine forests to fire and fire surrogate treatments for wildfire hazard reduction and ecological restoration." National Fire and Fire Surrogate Study for Ecosystem Restoration, Fuel Treatments Workshop, 2005, 38-48.

[307] Ibid, 40.

federal, state, and local budget, this may be a tricky task; especially since funds are already dedicated to wildfire suppression.



Chip 3 - 5 inch trees

	$ / Acre			Dry Tons / Acre
Gross Revenue	$1,325		**Cut Trees (Biomass)**	22.9
Harvest Costs	$1,063		Logs Removed	11.5
Hauling Costs	$361		Chipped Trees	6.9
Mastication Costs	$0	☐ Check to include	Residue Collected	2.3
Mechanical Treatment Costs	$0	☐ Check to include	**Remaining Activity Fuels**	2.1
Prescribed Burn Costs	$0	☐ Check to include	**Pretreatment Surface Fuels**	15.0
Other Costs (user specified)	$0		Masticated Fuels	0.0
Net revenue per acre	-$99		Fuels Burned	0.0
	CCF / Acre			
Volume of Logs	8.4		**Remaining Surface Fuels**	17.1

a

Pile and burn 3 - 5 inch trees

	$ / Acre			Dry Tons / Acre
Gross Revenue	$1,186		**Cut Trees (Biomass)**	22.9
Harvest Costs	$597		Logs Removed	11.5
Hauling Costs	$201		Chipped Trees	0.0
Mastication Costs	$0	☐ Check to include	Residue Collected	0.0
Mechanical Treatment Costs	$368	☑ Check to include	**Remaining Activity Fuels**	11.4
Prescribed Burn Costs	$21	☑ Check to include	**Pretreatment Surface Fuels**	15.0
Other Costs (user specified)	$0		Masticated Fuels	0.0
Net revenue per acre	$0		Fuels Burned	11.4
	CCF / Acre		**Surface Fuels Remaining**	
Volume of Logs	8.4		**After Prescribed Fire**	15.0

b

Figure 1: Net Cost of Thinning Trees in Oregon. Source:. Fight, Roger D, and Barbour, R. James. "Financial analysis of fuel treatments." *Financial Analysis of Fuel Treatments on National Forests in the Western United States*. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, 20.

Limitations of Mechanical Methods

There are several different types of mechanical methods for managing wildfire, including timber harvests, baling and bundling, and mastication. Timber harvests mean falling trees and removing them from the area to sell, baling and bundling are two processes of compressing loose biomass, and mastication reduces biomass to small chunks or chips.[308] Each of these methods are applied for different operational characteristics and have downsides, especially in terms of budget and cost.

One major problem of mastication is the machinery itself. A study on the efficacy and cost of the mastication found that the machine blade would often bounce off of the forest floor,

---

308 Mitchell, Dana, and Smidt, Mathew. "Costs of Mechanical Fuel Reduction Treatments." *Encyclopedia of Wildfires and Wildland-Urban Interface (WUI) Fires*, Springer International Publishing, Cham, 2020, 149–155. <https://doi.org/ 10.1007/978-3-319-51727-8_139-1>.

leaving swaths of fuels intact.[309] This could result in higher costs to complete the job, as the machinery may have to pass over the area several times before completely eradicating the targeted fuels. Combining the costs of the mastication equipment (rented by the hour), personnel, and fuel, a single day of mastication work can be quite expensive with fairly low returns.

Land Use Approaches

Different land use approaches can be used for risk mitigation and fire management, but each have their own shortfalls. The most major challenges for private landowners are cost, time, and trust in the government. While some WUI communities may require the public to alter their property to be more fire resistant, other communities may not. Regardless, the cost of doing this can be substantial. For federal, state, and local governments, land use approach limitations can take the form of the democratic and bureaucratic process and relations.

Private Property Landowner Limitations

Cost is the biggest constraint in terms of land use. According to an Australian study that examined the cost to brace private land for wildfire, alterations on average can cost approximately $8,000, plus an additional $1,000 per year for repairs.[310] This includes adding fencing and modifying landscape. For rural landowners in the WUI, this may not be completely feasible from a financial point of view. If there is a lack of or inadequate funding for local or state programs going to aid fire resistant renovations, property owners may not be able to afford any or all of the recommended measures. When this occurs, the private owner's community may be put in jeopardy due to the lack of fire-resistant applications. Additionally, the sheer number of alterations needed for single landowners can be quite staggering. Landowners must take care of reducing fuels around their homes and property, make adjustments to the structure of their home, purchase or rent the equipment needed to do so, purchase survival equipment, design survival plans, purchase insurance (which can be incredibly high for fire-prone areas), and ensure that homes and businesses are up to code. The cost and time commitment for all of these measures is a serious downside for private property owners and because of this, "only a small proportion of residents adequately prepare for wildfire."[311]

In addition, the public's trust that the government will sufficiently protect their property through fire suppression or fire management can hinder fire resistant alterations to property. This

---

[309] Dodson, Elizabeth. 2016. "Cost, production, and effectiveness of masticated fireline." Proceedings of the 2016 COFE and Demo International 2016 Technical Conference. Canada's Forest Sector, Adapting to a New Reality. Vancouver, BC, Canada. Sept. 2016, 5.

[310] Penman, T.D, et al. "How Much Does It Cost Residents to Prepare Their Property for Wildfire?" *International Journal of Disaster Risk Reduction*, vol. 16, 2016, 88–98.

[311] Penman, T.D, et al. "How Much Does It Cost Residents to Prepare Their Property for Wildfire?" *International Journal of Disaster Risk Reduction*, vol. 16, 2016, 88–98.

can be chalked up to a lack of understanding of wildfire and a lack of communication between the federal, state, and local governments and private property owners. Similarly, mandatory insurance may lead private landowners to believe that any property damaged or lost during a fire can be easily replaced or reimbursed.[312] These mindsets may discourage landowners from implementing fire resistance measures on their property which puts their properties, lives, and communities at risk.

Institutional Limitations

Institutional limitations for land use approaches include bureaucratic organizational issues and administration rules. This is because laws, policies, administrative rules, and procedures "can slow down implementation of wildfire mitigation strategies on Federal lands."[313] This may also hold true for state-owned land as well. Landscaping regulations, building codes, watershed management, steep slope ordinances, land use development codes, and subdivision design standards are all controlled under local government regulations.[314] Determining when and how to carry out risk mitigation methods can take a long time, especially since the ordinances such as these must go through the democratic process of specialized committees, city council meetings, public hearings, and voting. When time is of the essence, particularly in fire-prone areas in the west coast region that need immediate support, this can be a tiring and tedious process that requires public and leadership support. Some communities may not be adequately prepared for this cost. Furthermore, strategies such as these are paid with taxpayer dollars.

Community-Based Approaches

Land use approaches often coincide with community-based approaches for wildfire management and risk mitigation. Land use planning that includes fire resilience as a priority can do a great deal to prevent damage to public and private property.

Because of this, many communities adopt Community Wildfire Protection Plans (CWPPs). While these plans have many merits, there are problems to consider. For example, one of the most critical limitations of CWPPs is that they are not legally binding. CWPPs are suggestions and recommendations for strategies to prevent and protect against wildfire. However, since they are not legally binding, communities do not need to implement any or all of

---

312 Ibid.

313 Anthony S Cheng and Dennis R Becker. "PUBLIC PERSPECTIVES ON THE 'WILDFIRE PROBLEM.'" *Fire Management Today,* vol. 65, no. 3, 2005, 12.

314 Community Planning Assistance for Wildfire. "Land Use Planning." *Community Planning Assistance for Wildfire, Headwaters Economics*, 6 Feb. 2019, cpaw.headwaterseconomics.org/what-we-do/land-use-consulting-advice/.

the measures listed in the CWPP. Some communities may choose not to implement the CWPP for various reasons such as cost, lack of personnel, or more. This can greatly undercut the effectiveness of CWPP strategies and methods, putting communities at risk for wildfire.

Intergovernmental Misalignment

One major limitation for federal, state, and local governments is working together cohesively. One study found that intergovernmental mission misalignment is a critical barrier for wildfire management and risk mitigation.[315] This is problematic because government structure and interrelationships can lead to conflict and mismanagement. Considering how wildfires do not follow local or state boundaries, governments from many jurisdictions must collaborate to manage fire. The study in question discovered that mission misalignment within agencies "may reflect the strategic decisions of agencies to serve divergent yet meaningful purposes" that may prove incredibly harmful to communities and ecosystems.[316] This is an alarming issue, especially considering how government collaboration, when used effectively, is a critical tool for fire management and risk mitigation.

Tensions and misalignment can come from agencies with different goals. For example, the U.S. Forest Service (USFS) and state governments have different purposes, meaning they do not necessarily share the same goals. This may cause confusion and hamper public trust in different levels of government. The study found a quantitative difference in mission goals within the three different levels of government in relation to wildfire management and how they were perceived within those organizations.[317] While Incident Command Structure (ICS) is used to determine positions in intergovernmental response to wildfires, "conflicting mandates and priorities" on all levels of government can cause tension and confusion.[318] Understanding these barriers for federal, state, and local governments to work together on fire management and risk mitigation is key to a cohesive and collaborative response to uncontrolled and unplanned wildfires. While it may all boil down to communication, the number of agencies involved with planning, preparing, and responding to fire should be considered. With wildfire, it may be difficult to determine whether less is more or more is less.

Public and Private Landowner Rules and Awareness

Landowner rules can impose burdens.

---

[315] Casey J. Fleming, et al. "Conflict and Collaboration in Wildfire Management: The Role of Mission Alignment." *Public Administration Review*, vol. 75, no. 3, 2015, 445–454.

[316] Ibid.

[317] Ibid.

[318] Casey J. Fleming, et al. "Conflict and Collaboration in Wildfire Management: The Role of Mission Alignment." *Public Administration Review*, vol. 75, no. 3, 2015, 445–454.

Procedure Limitations for Private Landowners

Limitations for prescribed fires fall into two categories. There is the managerial side, which involves the approval procedure and the budget. These are important because while they have less to do with the physical barriers of prescribed burning, they are tedious and complicated. Additionally, problems such as these primarily apply to individual and private landowners that intend to conduct a prescribed burn. This is due to the fact that the state has more internal structure and procedure to deal with this while landowners may not have the resources available. The second is the technical and environmental side, which includes determining possible locations, seasons, and all negative ecological side effects from the burning. These barriers include how prescribed burning affects certain environments from small to large scale change. While these are separate categories, they are certainly not distinct from one another due to how they relate. The administrative side must consider the ecological effects and the local and state policies that may make some prescribed burns or thinning illegal. For the technical and environmental side, the budget and cost of the burn may be too expensive to carry out.

Beginning with the managerial side, the approval procedure for conducting prescribed fires is somewhat complicated. Each state has its own procedures and avenues to navigate in order to get a burn approved. California, for example, has three separate ways to get a burn permit[319]. Determining which way is most appropriate for a certain area can be complicated and is not necessarily very clear. There are also two different types of permits, which are for state and local agencies and for landowners dealing with non-federal land[320]. In addition to this, a full team of at least nine people is needed to fulfill leadership positions for the permit. The positions include unit chief, coordinator, prescribed fire incident commander, fire effects monitor, resource specialist, and more[321]. This means that a private landowner who wants to perform a prescribed burn on their property will need to enlist the assistance of their family, neighbors, local fire department, and possibly many others; all of which need training to be qualified for each role. This severely limits who can conduct a prescribed burn, especially in areas where training is hard to come by or in super rural areas where all the fire and safety equipment is needed is not available. This problem may not apply to the state forestry department that intends to do a controlled burn because it already has the proper equipment and fire technicians trained. The rest of the process itself is a challenge, given how many forms must be filled out and how many plans must be made, all of which need to be approved one by one.

---

319 CAL FIRE Prescribed Fire Working Group. “CAL FIRE Prescribed Burn Guidebook.” California Department of Forestry and Fire Protection, Sept. 2019, 3.

320 Ibid, 5.

321 Ibid, 6-10.

Liability is a major roadblock to this process because the state determines how much responsibility it will take for the prescribed burn.[322] This means that private landowners have to be meticulous in planning in order to essentially convince the state to take most or all of the liability. On state-owned land, this is not a problem because the state is already liable for the land and can skip this step. In California, burn permits require operational complexity analysis forms, safety and risk management forms, liability determination, live fire use approval, final checklists, burn plans, contingency plans, environmental review forms, consultations from the state forestry department, smoke management plans, financial reports, and wildfire declaration plans.[323] This long train of requirements demonstrates how many hoops must be jumped through in order to simply gain a burn permit. For private landowners, this may appear to be a daunting and overwhelming task and may prevent them from attempting this process of fire management. This process takes a long time, so if weather conditions or another factor go wrong after everything is approved, the window for the burn may be missed. Even though this laundry list of forms is necessary for the safety and efficacy of the planned burn, in tandem with seasons, weather, and climate restrictions, it is a miracle any prescribed burns happen on the west coast at all.

The Smokey Bear Shortcoming

As was mentioned earlier, Smokey Bear is a symbol that is well-known in the west coast region of the United States. A character that is championed for the phrase "only YOU can prevent wildfires" during a time in the US when fire suppression was the main tactic for controlling wildfire, the bear now represents an outdated view that pushes the wrong message onto the public. Smokey pushes the idea that aggressive wildfire suppression is the best way to protect the public. This has led to an accumulation of fuels which has resulted in higher frequency and severity of fires. Now it is generally understood that wildfire management through controlled burns is much more beneficial for preventing frequent high severity fires. Because of the public's acceptance of Smokey Bear, he represents a major shortcoming of the government, which believed that "the message that fire was sometimes good and sometimes bad was considered too sophisticated for the general public."[324] This is a major barrier to government versus public communication and changing the public's perception of wildfire will be challenging, especially considering how ingrained Smokey's message is in the general public. Smokey Bear himself is a problem for the public's understanding of good versus bad wildland fires. Since the character itself is very friendly and easily digestible for a general audience, changing Smokey Bear's message may adjust public perception to controlled burns. A study

---

322 CAL FIRE Prescribed Fire Working Group. "CAL FIRE Prescribed Burn Guidebook." California Department of Forestry and Fire Protection, Sept. 2019, 10-23.

323 Ibid.

324 Geoffrey H. Donovan, and Thomas C. Brown. "Be Careful What You Wish for: The Legacy of Smokey Bear." *Frontiers in Ecology and the Environment*, vol. 5, no. 2, 2007, 73–79.

done by the US Department of Agriculture and National Forest Service found that when comparing propaganda with or without Smokey's face, 69% of viewers could recall verbatim what the propaganda sign said, with some discussion.[325] Given this, Smokey's message is a limitation for wildfire management because of the vast number of people who recognize it. Evolving Smokey's message to focus more on fire management instead of suppression may change this.

Communication Limitations

Communication between federal, state, local governments, and the general public has several different limitations. From the public perspective, the communication breakdown can be broken down into categories including place, belonging, property, and public environment due to social values. From the government perspective, deeply understanding communities and their needs can be a roadblock for gaining public support for fire mitigation practices.

Social values are a critical part of WUI communities. Since many people choose to live in the WUI due to scenery, environment, and comfort, some fire management methods may be unwelcome.[326] For example, thinning or prescribed burns around peoples' homes may completely undermine the entire decision to live in the WUI because it removes the sense of seclusion and privacy. Removing all the understory fuels to maintain the peaceful and "natural" atmosphere may cause agitation and opposition from landowners in the WUI. Another social value is that of public environmental resources. While government agencies may see risk reduction and mitigation as the clear solution for ecosystems and WUI, constituents in functioning ecosystems of historical fire regimes may be willing to risk certain resources in the short term in order to maintain them in the long term.[327] This may result in a breakdown in communication between the public and the government because the public may not fully understand what the risk mitigation and fire management practices may include. Additionally, communities perceive wildfire differently. For example, families may prioritize the risk of car accidents or disease (especially during the global pandemic) over the threat of wildfire.[328] This could substantially influence the time and energy communities are willing to put into wildfire risk mitigation of their communities.

Government communication is another roadblock for ensuring communities are on board with risk mitigation. This is especially important because WUI communities are not one and the

---

[325] Folkman, William S. "Modifying the communicative effectiveness of fire prevention signs." Res. Note PSW-RN-104. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 1966, 8.

[326] Anthony S Cheng and Dennis R Becker. "PUBLIC PERSPECTIVES ON THE 'WILDFIRE PROBLEM.'" *Fire Management Today,* vol. 65, no. 3, 2005, 12.

[327] Ibid, 12-15.

[328] Ibid, 14.

same—each community has its own dynamics, history, experiences with wildfire and land management, and openness to government intervention. For example, indigenous nations have a long history when dealing with wildfires that may be complicated. Some communities may have people and organizations that are skilled in preparing for wildfire and may not need the same risk mitigation techniques in place that others may. Some communities may have more individuals than others that are interested in volunteering to educate on wildfire awareness. These are limitations in the sense that a deep understanding of each community in the WUI is necessary for local and state governments when implementing risk and fire management. If governments treat each community the same, the efficacy may be challenged.

More communication challenges are in the form of medium. A report from the US Department of Agriculture and the US Forest Service found that people respond much better to interpersonal communication, rather than mass media.[329] Engaging communities through their elected and unelected leaders (such as ministers, local newspapers, teachers, and scout leaders) and peers is more effective. However, figuring out how to get such people involved may be a challenge and is more difficult than sending out newsletters and television advertisements. Lastly, a major hindrance in communication is, to put it plainly, talking the talk and not walking the walk. People in WUIs may indicate that they approve of fire management and risk mitigation practices, however that does not mean that they will actively participate in these efforts.

Infrastructure Maintenance

Infrastructure maintenance is a key aspect of wildfire management and risk mitigation, especially with electrical infrastructure and road maintenance. However, it has numerous limitations including time, constant attention, and cost. When infrastructures such as these are not actively maintained, they can result in serious danger for the public, especially during or causing wildfires.

Pacific Gas & Electric Corporation (PG&E), which is overseen by the California Utilities Commission, is responsible for maintaining all of the powerlines and the electric system within California. Perhaps famously, in 2019, one of its high-voltage power lines resulted in one of the deadliest wildfires in California history.[330] While the company retired the powerline, there are still severe issues with at least ten transmission towers and lines in California. This sheds light on how electric infrastructure maintenance is crucial to prevent uncontrolled fires. Time is an important constraint to consider when thinking about infrastructure maintenance. In PG&E's

---

[329] Anthony S Cheng and Dennis R Becker. "PUBLIC PERSPECTIVES ON THE 'WILDFIRE PROBLEM.'" *Fire Management Today,* vol. 65, no. 3, 2005, 14.

[330] Blunt, Katherine. "PG&E Retires Power Line that Sparked California's Deadliest Wildfire; Inspections have found that the Utility Needs to Make Thousands of Repairs to its Electric System." *Wall Street Journal (Online)*, Jun 19, 2019. *ProQuest*, https://search.proquest.com/newspapers/pg-amp-e-retires-power-line-that-sparked/docview/2243087234/se-2?accountid=14784.

case, the estimated time was over a year to make the necessary repairs. Since the wildfire season in California is at least four months long, being able to make the repairs in time is incredibly hard to achieve. This puts the at-risk towers in jeopardy and with it, the public that lives around it. At the same time, constant maintenance is needed to prune and cut away trees from power lines. Unless the company is actively monitoring all of its transmission lines, it is up to communities to notify it. This can cause a backlog of maintenance requests or the company may not be notified at all until it is too late. In the 2019 case with PG&E, cost was another major factor for infrastructure maintenance. In fact, the improvements needed to repair the at-risk towers was estimated at $2.3 billion.[331] Although this is a small number compared to the $30 billion estimated for liability costs due to the powerline failure, it is still a substantial sum and must be considered as a problem for infrastructure. This costs taxpayer money that the public may not approve of.

Another major limitation of infrastructure is road maintenance. Roads are incredibly important for fire management and risk mitigation for many reasons including fuel breaks, fire breaks, and transportation for fire management or for evacuations.[332] The main maintenance concerns with roads is how backlogged repairs can be. In WUI, especially WUI that is not heavily inhabited, road maintenance may not be prioritized. This can be dangerous not only for people if they need to evacuate their homes, but also for fire technicians when they fight fires.

Conclusion

Fire management benefits greatly outweigh their drawbacks. Yet an essential part of any successful management program is to understand the limitations of its various elements. Both the complexity of wildfire risk and the many stakeholders involved require a flexible, clear-eyed approach that takes account of where such barriers lie.

- With methods such as prescribed burning, thinning, and mastication, the main deterrents are administrative and environmental. Lack of trained personnel and limited budgets can severely curb the amount of space that could otherwise be managed. Environmental constraints from prescribed burning are the effects on water quality and eutrophication, diversity of understory vegetation, and air quality.
- Cost to private landowners is an issue for land use approaches, which can be a major deterrent for implementing fire resistant measures. At the same time, land use ordinances, laws, policies, and regulations for fire protection all must go through the democratic process, which can take a substantial amount of time. In fire-prone areas, that time may not exist.

---

[331] Ibid.

[332] Matthew P. Thompson, et al. “Forest Roads and Operational Wildfire Response Planning.” *Forests*, vol. 12, no. 110, 2021, 110.

- For community-based approaches, limitations take the form of CWPPs. While extremely helpful in terms of recommendations and planning for wildfires, are not legally binding. This means that communities that lack resources or manpower to implement the CWPP suggestions do not need to take action.
- Government misalignment is a problem because different levels of government all are involved with fire management, and different agencies can have conflicting missions for fire management, which may lead to confusion and a lack of public trust.
- The procedure to get controlled burns approved for private landowners is incredibly complicated and hard to navigate, which may deter landowners from attempting prescribed burns on land that is at-risk for wildfire.
- Breakdowns in communication between the public and the government in terms of risk mitigation should be considered. The Smokey Bear character has pushed the idea that all fires are harmful, which has led the public to wrongly characterize prescribed burns as dangerous and to be avoided. Likewise, there is a disconnect between communities and the government due to social values, a lack of initiative by the public, and a lack of understanding of community dynamics from the government.
- Maintenance infrastructure barriers include time, attention, and cost; all of which are hard to come by. A lack of electric infrastructure maintenance has deadly consequences, so consistent repairs are necessary.

Works Cited

Antony S Cheng, and Dennis R Becker. “PUBLIC PERSPECTIVES ON THE ‘WILDFIRE PROBLEM.’” *Fire Management Today*, vol. 65, no. 3, 2005, 12.

Blunt, Katherine. "PG&E Retires Power Line that Sparked California's Deadliest Wildfire; Inspections have found that the Utility Needs to make Thousands of Repairs to its Electric System." *Wall Street Journal (Online)*, Jun 19, 2019. ProQuest, https://search.proquest.com/newspapers/pg-amp-e-retires-power-line-that-sparked/docview/2243087234/se-2?accountid=14784.

Brockway, Dale G.; Outcalt, Kenneth W. “Understory vegetation response in longleaf pine forests to fire and fire surrogate treatments for wildfire hazard reduction and ecological restoration.” National Fire and Fire Surrogate Study for Ecosystem Restoration, Fuel Treatments Workshop, 2005, 38-48.

CAL FIRE Prescribed Fire Working Group. “CAL FIRE Prescribed Burn Guidebook.” California Department of Forestry and Fire Protection, Sept. 2019, 3.

Casey J. Fleming, et al. “Conflict and Collaboration in Wildfire Management: The Role of Mission Alignment.” *Public Administration Review*, vol. 75, no. 3, 2015, 445–454.

Cleaves, David A., et al. *Influences on Prescribed Burning Activity and Costs in the National Forest System*. U.S. Dept. of Agriculture, Forest Service, Southern Research Station, 2001, 1.

Community Planning Assistance for Wildfire. “Land Use Planning.” *Community Planning Assistance for Wildfire, Headwaters Economics*, 6 Feb. 2019, cpaw.headwaterseconomics.org/what-we-do/land-use-consulting-advice/.

Dodson, Elizabeth. 2016. “Cost, production, and effectiveness of masticated fireline.” Proceedings of the 2016 COFE and Demo International 2016 Technical Conference. Canada’s Forest Sector, Adapting to a New Reality. Vancouver, BC, Canada. Sept. 2016, 5.

Fight, Roger D, and Barbour, R. James. “Financial analysis of fuel treatments.” *Financial Analysis of Fuel Treatments on National Forests in the Western United States*.

U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, 20.

Folkman, William S. “Modifying the communicative effectiveness of fire prevention signs.” *Res. Note PSW-RN-104. Berkeley, CA*: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 1966, 8.

Geoffrey H. Donovan, and Thomas C. Brown. “Be Careful What You Wish for: The Legacy of Smokey Bear.” *Frontiers in Ecology and the Environment*, vol. 5, no. 2, 2007, 73–79.

Matthew P. Thompson, et al. “Forest Roads and Operational Wildfire Response Planning.” *Forests*, vol. 12, no. 110, 2021, 110.

Meek, M.G, et al. “White-Tailed Deer Distribution in Response to Patch Burning on Rangeland.” *Journal of Arid Environments*, vol. 72, no. 11, 2008, 2026–2033.

Mitchell, Dana, and Smidt, Mathew. “Costs of Mechanical Fuel Reduction Treatments.” *Encyclopedia of Wildfires and Wildland-Urban Interface (WUI) Fires*, Springer International Publishing, Cham, 2020, 149–155. <https://doi.org/10.1007/978-3-319-51727-8_139-1>.

Orlova, Julia, et al. “Effects of Prescribed Burn on Nutrient and Dissolved Organic Matter Characteristics in Peatland Shallow Groundwater.” *Fire (Basel, Switzerland)*, vol. 3, no. 3, 2020, 3, 53.

Penman, T.D, et al. “How Much Does It Cost Residents to Prepare Their Property for Wildfire?” *International Journal of Disaster Risk Reduction*, vol. 16, 2016, 88–98.

Zald, Harold S. J, et al. “Limited Effects of Long-Term Repeated Season and Interval of Prescribed Burning on Understory Vegetation Compositional Trajectories and Indicator Species in Ponderosa Pine Forests of Northeastern Oregon, USA.” *Forests*, vol. 11, no. 8, 2020, p. 834. <https://doi.org/10.3390/f11080834>.

Policy Recommendations

Kristian Whittaker, Rachel Demaree, Jason Hurwitz, and Bailey Ramsdell

Because fire conditions vary so drastically on the west coast, policy recommendations must differ as well. Our approach has been to provide broad recommendations that apply to the West Coast as a region and would need to be adapted strategically on a local basis. Individual policies will inevitably vary in their applicability to specific locales and communities. We also appreciate that there can be a lack of trust among organizations and limited funding that may constrain actual implementation. Human dimensions to wildfire risk are rarely simple or entirely straightforward.

Prioritize Research on Wildfire Smoke: To further protect all populations affected by wildfires, it is crucial for further research to be pursued on smoke-related impacts and issues. Doing so will allow for greater preparation and understanding of the dangers of wildfire smoke to help prepare for the future. We recommend continued research in the following areas: exploring differences in urban PM and wildfire PM as well as ways to differentiate between the two, the specific types of microbes carried within wildfire smoke, the long-term health outcomes, the impact on marine ecosystems, and potential future smoke pathways

Prioritize Resources for Those Most Vulnerable: For those of lower income, who suffer from chronic illness, or who live in relatively isolated areas, the impacts of wildfires can be particularly disruptive and onerous. In order to protect these communities and ensure safety for everyone more resources need to be considered or provided. Regarding wildfire smoke, this could include HEPA filters and fire-kits that include N-95 masks. Options should be available to help feed families through means such as food stamps and food deliveries, as research has shown that those with less access to food have a greater risk of negative health outcomes from wildfire smoke. During fire season, and perhaps year-round, vulnerable populations in high-risk areas could benefit from a "Fire Hotline" to an emergency center, prepared to offer aid.

Consider Providing Emergency Aid Plans for Urban Areas: People in large population centers, such as Seattle, Portland, and San Francisco, have been increasingly exposed to toxic wildfire smoke in the past decade. Such exposure is very likely to continue and even worsen. Cities should consider establishing programs to advise people on how to protect themselves and possibly seek aid, including shelter, at times when smoke events are especially dense, long, and therefore threatening. "Fire kits," echoing those for earthquakes, containing masks and first aid materials, could be created and sold at minimal cost.

Increase Funding and Resources Where Ash Falls: When the wildfire smoke eventually clears out of the air and the ash falls, it produces harmful effects on the environment that are oftentimes irreversible. In order to ensure the safekeeping of areas where this will occur in the future or in areas where it has happened more than once, such as in Northern Utah, it's important for further funding and resources to help reverse the effects caused by the ash and falling contaminants. Contamination in areas such as Northern Utah is high and continues to place negative health effects on the community and the environment. Providing greater resources to clean up the land or water the ash falls on would be beneficial for the health of all populations now and in the future.

Prioritize Fire-Adapted Communities: In order to protect human life and developments, the following steps should be taken to maximize fire resistance in WUI and high-risk areas and set goals to become Fire-Wise communities. These communities should be required to work with a variety of stakeholders (such as tribal agencies) to adopt a CWPP that includes planning for post-fire challenges like homelessness and rebuilding structures. Local governments should be required to implement overlay zoning districts that specifically address wildfire risk mitigation to place greater emphasis on the protection of high-risk communities. An important aspect of this is to provide funding and education for residents to modify their properties to be better equipped to handle fires and the damage that often accompanies them. Newly built developments in the WUI and high-risk areas should adhere to fire-adapted codes. Lastly, state and local governments should be more proactive about communicating with WUI communities and tailor said communication to the specific needs of each community.

Increase Utility Company Oversight: Due to infrastructure concerns such as electricity and road maintenance, California, Washington, and Oregon governments should consider or evaluate the possible need to establish better utility oversight within public utility commissions. This may include ensuring more frequent maintenance of equipment and tree trimming or other clearing of material near telephone poles and transmission/distribution lines. Planning for improved responses to loss of electricity and other infrastructure in fire-prone areas is also advised where not already done. Such planning should involve consideration of interstate as well as in-state power networks.

Increase Wildfire Awareness Education: Current education programs have shown significant success in curtailing human ignitions and in stopping wildfires over the last century (which has in turn allowed for serious fuel buildup). However, much education is still needed addressing prescribed burns, the dangers of smoke, living in the WUI, and other important areas.

Educational programs need to stress that fire is a natural part of forest livelihood and that we must learn to live with it instead of suppressing it as we have done. In terms of prescribed burns, trust needs to be rebuilt between the DNR and WUI communities who often see fuel treatment and thinning simply as an excuse for logging. These educational programs could be implemented in public schools, community education programs, and online seminars.

Utilize Existing Informational Channels: Smokey the Bear is a well-known and much-loved figure in the United States and is arguably one of the best media successes of any governmental campaign. Instead of doing an about-face and telling people not to listen to Smokey, the DNR should continue to use Smokey's likeness to advertise the new educational programs outlined above, focusing on living with wildfires instead of suppressing them. Social media will make this outreach campaign significantly more effective than it would have been in the past, and the increase in interest in outdoor recreation and living over the past decade should mean a large and receptive audience.

Increase Funding and Utilization of Fuel Treatment Techniques: Re-allocate funding whenever possible from fire suppression to preemptive fuel treatment such as thinning and prescribed burns. Local fire districts should keep detailed records of fuel treatments in order to track results and anticipate future treatment dates. Areas of potential concern should be treated sooner rather than later, using whichever techniques are most appropriate for each forest type.

Increase Research into Fuel Treatment Techniques: More research is needed to determine exactly what type of fuel treatment method works best in each climate, region, and biome. Additional research is also needed regarding the long-term repercussions of fuel treatment, and how to keep forests healthy during and after fuel treatment. This should include further research is needed on the potential climate impacts of prescribed burns.

Establish Better Intergovernmental Teamwork: Considering how intergovernmental organizations have different goals when it comes to wildfire, they should better align their strategies and priorities and increase internal communication. This will prevent confusion and misinformation from spreading and will allow WUI communities and ecosystems to be better protected. A key part of this teamwork would be establishing a common metric for assessing the economic effects of wildfires. In particular, it is especially important to observe natural resource and structure loss to long-term community health consequences in order to better anticipate necessary funding.

Further Research on Climate Change: Since climate change has become a driver of increased wildfires, continued study is strongly needed on the detailed aspects of this relationship, how they vary from one location to another, and how such knowledge can be utilized in forecasting and wildfire risk mitigation. Statewide and more local-level information in this domain could be of significant practical benefit, especially over time.

More Funding for Fire-Fighter Safety: Given the drastic increase in size, intensity, and longevity of West Coast fires, we recommend securing more funding to ensure fire-fighting capabilities and fire-fighter safety. This could include more personnel, better equipment, better compensation, and a plethora of other upgrades to current fire-fighting teams.