EVERYTHING YOU WANTED TO KNOW ABOUT WILDLAND FIRES IN FORESTS BUT WERE AFRAID TO ASK: LESSONS LEARNED, WAYS FORWARD

Salmon August fire in the Marble Mountains, California (L. Ruediger)

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EXECUTIVE SUMMARY

Wildfires are a fact of life for westerners. They mark the beginning of the spring season and have been a keystone architect of biodiverse ecosystems for millennia. While wildfires are not eco-catastrophes, they are a health concern, evoke public fear-of-fire exploited by decision makers seeking to push through anti-environmental policies, and generate conflicts over the best ways to coexist with this force of Nature that is not going away (nor should it), no matter how hard we try. This white paper summarizes some of the latest science around top-line wildfire issues, including areas of scientific agreement, disagreement, and ways to coexist with wildfire. It is a synopsis of current literature written for a lay audience and focused on six major fire topics:

1. Are wildfires ecological catastrophes?
2. Are acres burning increasing in forested areas?
3. Is high severity fire within large fire complexes (so called “mega-fires”) increasing?
4. What’s driving the recent increase in burned acres?
5. Does “active management” reduce wildfire occurrence or intensity?
6. Will more wildfire suppression spending make us safer?

Key findings

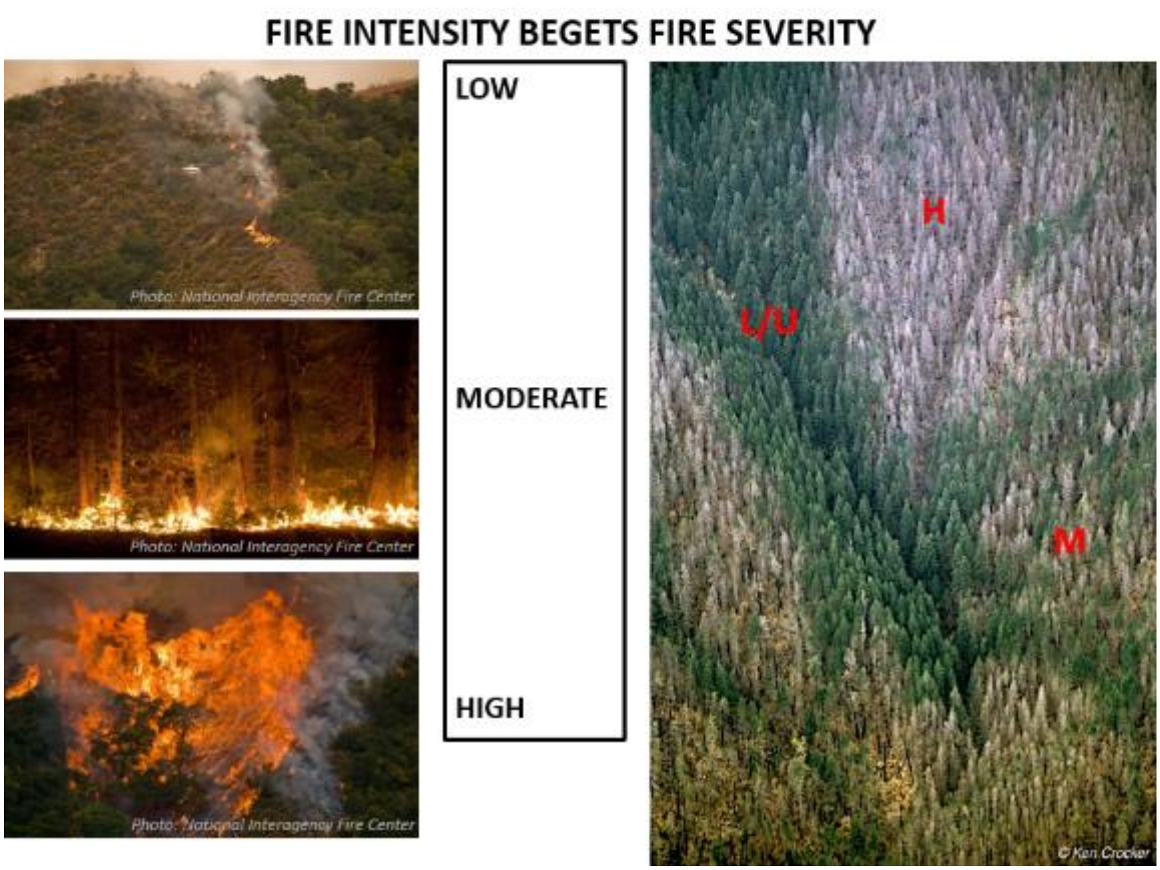
- Large wildland fire complexes, including patches of high severity fire, generate critical ecological pulses of dead trees (biological legacies) that are associated with extraordinary levels of biodiversity under-appreciated by most.
- Using long historical timelines, wildfire acres are currently at historical lows, but have been increasing in recent decades due mainly to three factors: (1) climate change; (2) human-caused fire ignitions (including suppression firing operations such as burnout and backfires); and (3) conversion of fire-resilient native forests to flammable plantations that experience relatively more high fire severity fire.
- Throwing more money at fire suppression will not abate fire concerns as more and more homes are built in indefensible places and are not designed or built with fire-resistant materials.
- Post-fire logging and associated activities (including roads) are unequivocally damaging to fire-rejuvenated forests and related aquatic ecosystems.
- Thinning small trees and prescribed burning can lower fire intensity at the stand level if done properly but this has significant limitations and ecological consequences given the scale of the perceived need and a changing climate.
- The most effective pathway to fire coexistence is to: (1) limit ex-urban sprawl through land-use zoning; (2) lower existing home ignition factors by working from the home-out with vegetation management and home retrofitting (defensible space), instead of the wildlands-in

(logging); (3) thin small trees and prescribe burn in ecologically appropriate settings (e.g., flammable plantations) while prioritizing wildland fire use in most forests away from homes; (4) store more carbon in ecosystems by protecting public forests and incentivizing carbon stewardship on non-federal lands; and (5) shift to a low-carbon economy as quickly as possible. Anything else will not achieve desired results to scale.

Issue 1: Are Wildfires “Catastrophic” or “Disastrous” Events?

Background

Large landscape wildfires are most often referred to as catastrophic “mass fires” or “megafires.” Demonizing wildfires has placed this natural process in the same conversation as hurricanes and floods. Such disaster-speak and presumed logging remedies are now inculcated in the “Wildfire **Disaster** Funding Act” (emphasis added) recently passed by Congress as part of federal omnibus appropriations that also included rollbacks to forest protections. But what really goes on after a wildfire may be surprising in terms of the high biodiversity and rejuvenation capacity of forests after large fires, including severe ones.



In general, fire effects are the result of heat energy released during a fire (fire intensity – left photos) and resulting effects on ecosystems (fire severity, right). Most large fires (right) produce a mosaic of burn severity effects on vegetation (H-high severity, M-moderate, Uunburned, L-low). Fire-mediated landscape heterogeneity is habitat for a diverse assortment of species distributed across the successional gradient (new to old forests) and has been referred to as "pyrodiversity begets biodiversity" (see below)[1]. Note – in some cases a fast-moving high-intensity "running" surface fire can produce low severity effects, while a slow-moving low intensity "creeping" fire can produce high severity effects (e.g., smoldering piles of slash or logs).

Issue 2: Are Total Wildfire Acres Burning Increasing (independent of severity)?

Background

Nearly every fire season, the news media and politicians announce another "unprecedented" wildfire season. Such proclamations are incorrectly based on comparisons of contemporary wildfire acres to a recent historical timeline. This has been widely criticized in the scientific literature as the "shifting baseline perspective" (i.e., when a baseline is shifted to a more recent historical time period)[2]. Importantly, in the early part of the 20th century during a warm climatic cycle (Pacific Decadal Oscillation - PDO), wildfire acres were at least five times more abundant than today. A mid-century cool down accompanied by industrial fire suppression resulted in a substantial decline in acres burning[3]. The current warm period is associated with a recent increase in both acres burning and fire suppression (see below). In other words, wildfire activity tracks broad-scale climatic phenomenon (top-down drivers) that also influence fire suppression efficacy.

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[1] DellaSala, D.A., and C.T. Hanson. 2015. The ecological importance of mixed-severity fires: nature's phoenix. Elsevier: Boston.

[2] See Jackson, B.C., et al. 2011. Shifting baselines. Island Press: DC.

[3] For an excellent historical resource read NY Times Best Seller, Timothy Egan's "The Big Burn." Mariner Books: NY.

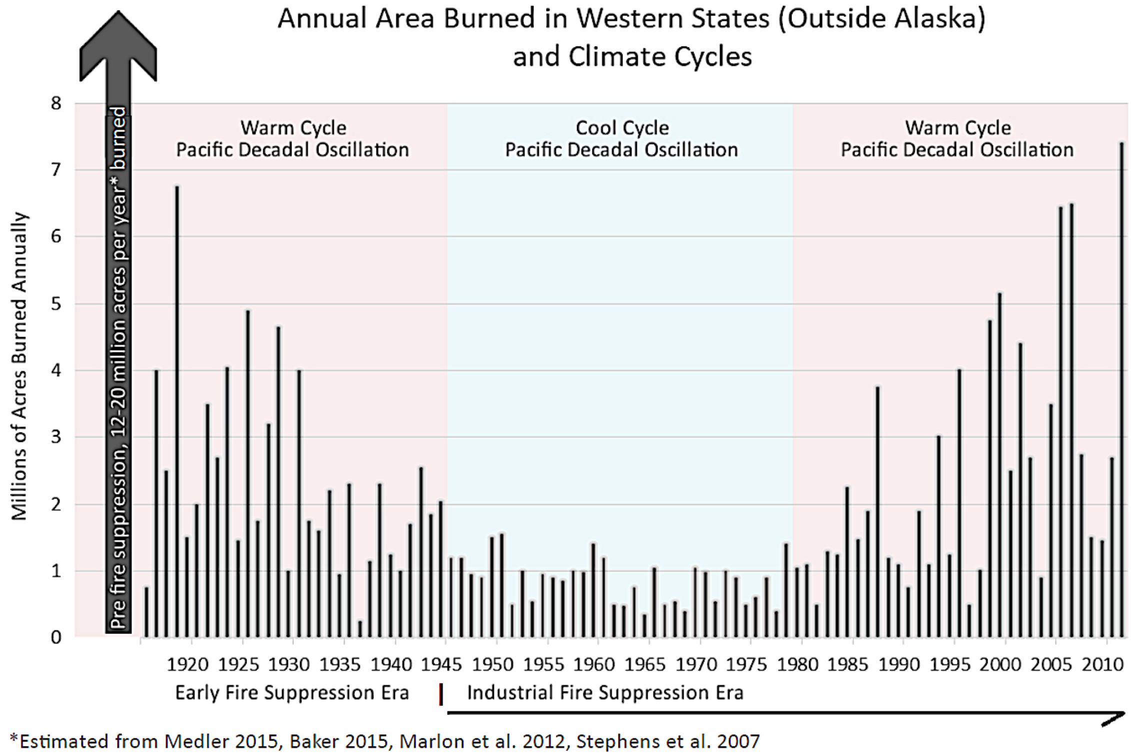

Figure interpretation caveats: prior to 1984, standardized datasets are difficult to obtain. Contemporary wildfires also have a strong back-burning influence not prevalent in historical times–i.e., errors in estimation exist on both ends of the wildfire acreage continuum. However, historical accounts (including General Land Office records and pollen-sediment core analyses) confirm very active fire seasons in the early part of the 20th century and before[4] (Figure compliments of John Muir Project).

Areas of Agreement

Fewer wildfire acres burning in forests today compared to the early 20th century has resulted in what many are calling a wildland fire deficit[5], which may seem as a surprise given fire hyperbole. The main exception to this deficit is southern California chaparral and shrub-steppe communities (too much human-caused fire is leading to ecosystem type conversions).

Areas of Disagreement

Current science debate is focused mainly on what is the best way for putting fire (i.e., “the right fire” “good fire”) back on the landscape in order to restore wildland fire-forest relationships.

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[4] Whitlock, C., et al. 2008. Long-term relations among fire, fuel, and climate in the north-western US based on lake-sediment studies. Int. J. Wildland Fire 17:72-83. Baker, W.L., and M.A. Williams. 2018. Land surveys show regional variability of historical fire regimes and dry forest structure of the western United States. Ecol. Applic. 28:284-290.
[5] Parks, S.A. et al. 2015. Wildland fire deficit and surplus in the western United States, 1984-2012. Ecosphere 6:275. 13 pp.

Many claim that this cannot be done safely without massive thinning to reduce “fuels”[6], others state that we need to get to coexistence with wildland fire as the amount of thinning needed is prohibitively costly[7], and has significant consequences to ecosystems (see below). Still others want more of the “right kind” of fire in the “right places”– meaning less high severity fire, despite ecological importance of this type in low to mid elevation pine and mixed conifer forests (i.e., even predominately low severity ponderosa pine systems have a component of high severity) throughout the West.

Issue 3: Is High Severity Fire Within Wildland Fire Complexes Increasing?

Background

High severity fires that kill most of the trees in older forests are associated with extraordinary levels of biodiversity not present in low severity burns due mainly to the abundance of biological legacies (e.g., snags and down logs, shrubs)[8]. This fact is now widely accepted by the scientific community; however, the amount and spatial distribution of high severity fire patches within wildland fire complexes remains in question as to whether ecosystem thresholds are being crossed in large fires.

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[6] Hessburg, P.F., et al. 2015. Restoring fire-prone Inland Pacific landscapes: seven core principles. Landscape Ecol. 30:1805-1835.

[7] Moritz, M.A., et a. 2014. Learning to coexist with wildfire. Nature 515:58-66.

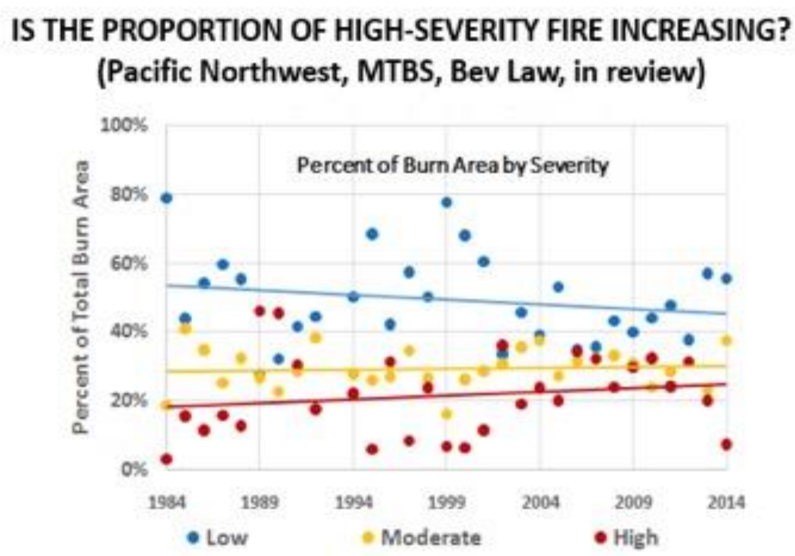
[8] Donato, D.C., J.L. Campbell, and J.F. Franklin. 2012. Multiple successional pathways and precocity in forest development: can some forests be born complex? J. Vegetation Science 23:576-585. DellaSala, D.A. and C.T. Hanson. 2015. The ecological importance of mixed-severity fires: nature’s phoenix. Elsevier: Boston.

High Severity Fire Patches Become Biodiverse Snag Forests

Complex early seral forest after 12 years of natural conifer regeneration, native shrub patches, and deciduous trees (C. Hansen, Eldorado Starr Fire, Sierra).

Areas of Agreement

Nearly all studies have detected no statistically significant trend in high severity acres or proportion of high severity fire within large fire complexes (Colorado is an exception and there is debate in the Sierra)[9].



This figure shows no discernable increase in percent of various fire severities in the Pacific Northwest over a three-decade period (compliments of Bev Law, Oregon State University). Data prior to 1984 are not available for fire severity comparisons.

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[9] Keyser, A., and A. LeRoy Westerling. 2017. Climate drives inter-annual variability in probability of high severity fire occurrence in the western United States.

Areas of Disagreement

Concern has now shifted to whether the size of high severity patches is increasing, believed to be a product of 21st century “mega-fires,” and whether this is leading to type conversions (forests to shrubs)[10]. High severity patch data obtained from hundreds of forest fires across the West show no statistical increase in patch sizes in recent decades (DellaSala et al. in peer review). This is important as the patch size debate is used to make claims about “mega-fires” and to justify large-scale thinning, post-fire logging, and tree planting based on perceptions of inadequate tree recruitment or lack of forest resilience to fires. However, most high severity patches have high levels of internal heterogeneity that include small patches of live trees or nearby low-moderate burn areas as seed sources (in review).

Issue 4: What’s Driving Recent Increases in Wildfire Acres Burning?

Background and Areas of Agreement

Recent increases in wildfire acres burning (see above PDO figure) can be traced to three main factors acting in concert: (1) a warming PDO from climate change; (2) increases in human-caused fire starts (accidental, arson, back burns); and (3) conversion of native forests to flammable tree plantations[11].

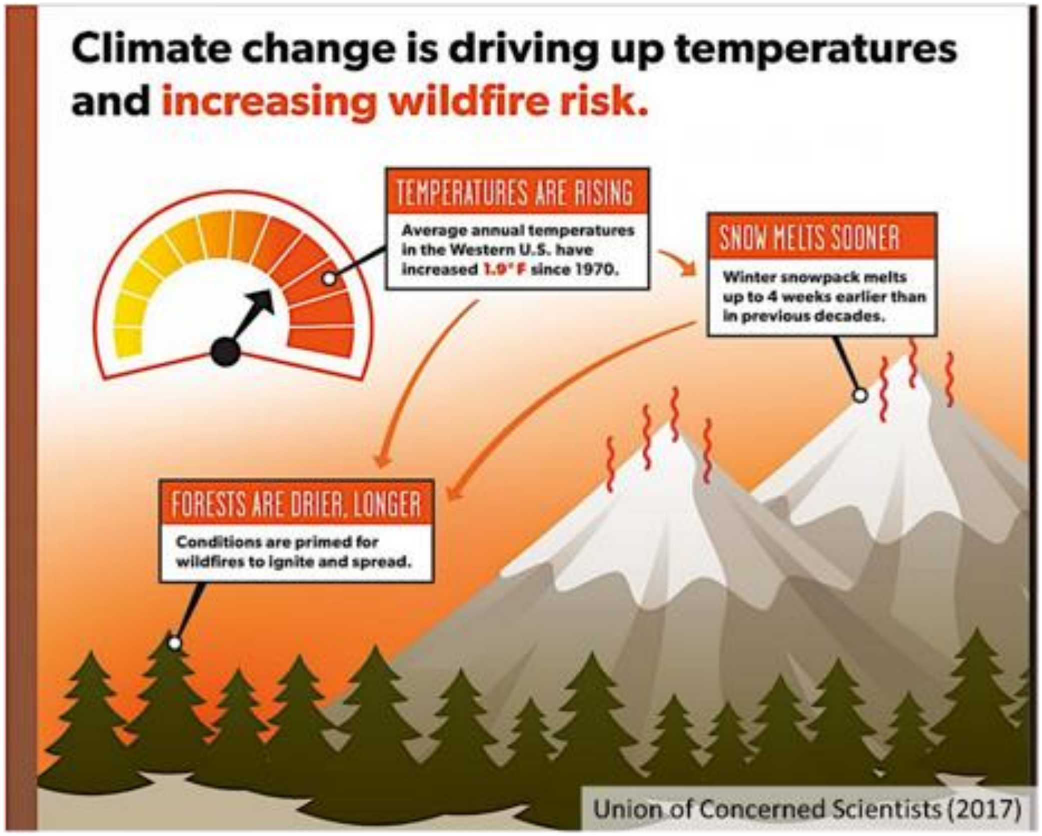
Over half of recent increases in wildfire acres burning has been attributed to climate change[12] (see top figure below as generalization) with 84% of all fire ignitions nationwide in recent decades caused by people (bottom figure below)[13]. Human-caused wildfire ignitions vary regionally based on population densities and remoteness.

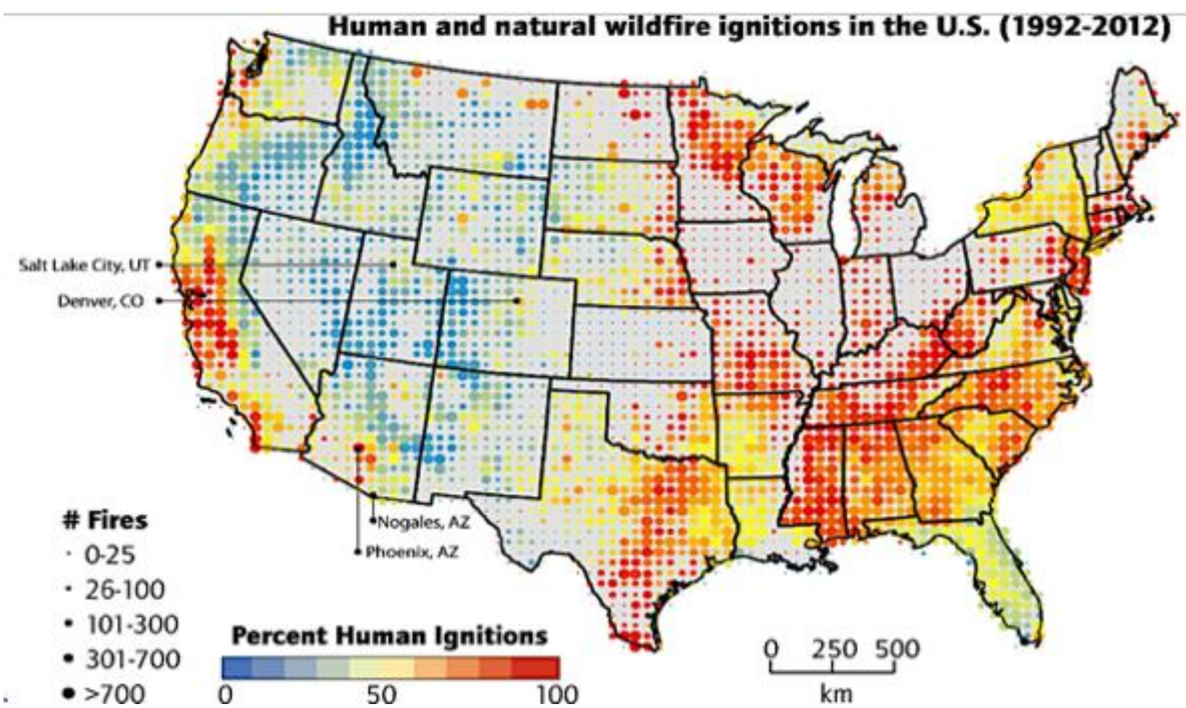
[10] Hessburg P.F. et al. 2015. Restoring fire-prone inland Pacific landscapes: Seven core principles. Landscape Ecology 30, 1805–1835.

[11] Bradley, C., C.T. Hanson, and D.A. DellaSala. 2016. Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western United States? Ecosphere 7:1-13. Odion, D.C., et al. 2004. Fire severity patterns and forest management in the Klamath National Forest, northwest California, USA. Conservation Biology 18:927-936

[12] Abatzoglou J.T., and A.P. Williams. 2016. Does Impact of anthropogenic climate change on wildfire across western US forests. PNAS 113:11770-11775

[13] Balch et al. 2017. Human-started wildfire expand the fire niche across the United States. PNAS 114:2946-2951.


Climate change is driving up temperatures and increasing wildfire risk.
TEMPERATURES ARE RISING
Average annual temperatures in the Western U.S. have increased 1.9° F since 1970.
SNOW MELTS SOONER
Winter snowpack melts up to 4 weeks earlier than in previous decades.
FORESTS ARE DRIER, LONGER
Conditions are primed for wildfires to ignite and spread.
Union of Concerned Scientists (2017)


Human and natural wildfire ignitions in the U.S. (1992-2012)
Salt Lake City, UT
Denver, CO
Nogales, AZ
Phoenix, AZ
Fires
0-25
26-100
101-300
301-700
>700
Percent Human Ignitions
0
50
100
0 250 500
km

Areas of Disagreement

While most land managers and decision makers are preoccupied with "fuels," two of the main drivers of fire behavior (climate change, human-caused ignitions) are largely ignored (except when used to justify logging for forest resilience). Additionally, roads (a principal source of human-caused fire ignitions) are almost never addressed in fire risk reduction measures. Uncertainty exists regarding whether large-scale thinning will work in a changing climate where fire behavior will be increasingly governed by extreme fire weather (high temperatures, low soil moisture, high winds, see below)[14]. Storing more carbon in ecosystems will help mitigate climate effects, although land managers often prioritize generating revenue from commercial sales over carbon storage[15].

Issue 5: Does "Active Management" Reduce Wildfire Intensity and Lower Fire Risks?

Background

Active management encompasses a wide spectrum of actions and opinions mostly focused on pre- (thinning) and post-fire ("salvage" logging) logging widely debated by scientists, conservation groups, and decision makers. This is arguably the number one area of fire-related conflicts on public lands with the underlying assumption that forests are overstocked, they need active management to reduce fire risks, and environmental safeguards are preventing management of forests that otherwise will burn out of control.

Areas of Agreement

Post-fire logging is unequivocally damaging to the pyrodiverse landscapes and complex early seral forests. In general, the larger the fire, the bigger the logging project[16]. Post-fire logging involves clearcutting both live and mostly dead trees, kills naturally regenerating conifers, and often is followed by herbicides to reduce competing yet beneficial vegetation and allow for subsequent planting of artificially grown trees (from nursery stock) in dense rows. As artificial plantations increasingly replace native forests, plantations act as kindling for intense fires (i.e.,

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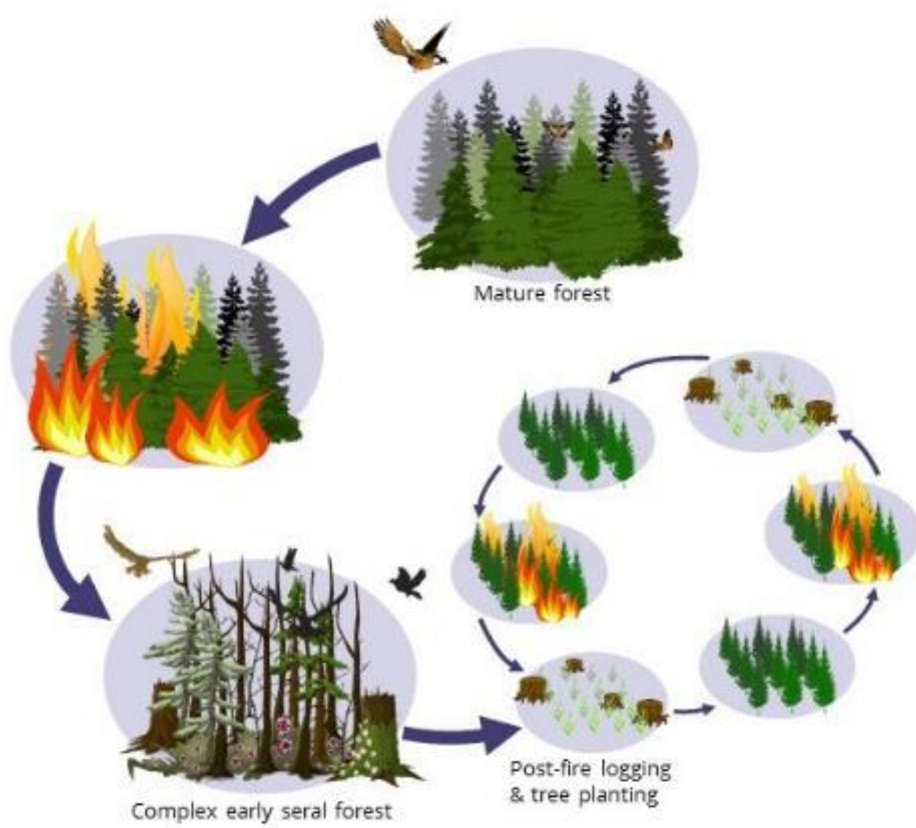
[14] Cary, G.J. et al. 2016. Importance of fuel treatment for limiting moderate-to-high intensity fire: findings from comparative fire modeling. Landscape Ecol. 32:1473–1483. Kalies, E.L., and L.L.Y. Kent. 2016. Tamm review: are fuel treatments effective at achieving ecological and social objectives? A systematic review. Forest Ecology and Management 375:84-95.

[15] Moritz, M.A. et al. 2014 (ibid). Law, B.E et al. 2018. Land use strategies to mitigate climate change in carbon dense temperate forests. PNAS http://www.pnas.org/cgi/doi/10.1073/pnas.1720064115

[16] DellaSala, D.A., et al. 2015. In the aftermath of fire: logging and related actions degrade mixed- and high-severity burn areas. Pp. 313-347, *In* DellaSala, D.A., and C.T. Hanson (eds), The ecological importance of mixed-severity fires: nature's phoenix. Elsevier, United Kingdom

"fire's gasoline")[17]. Post-fire logging creates a catastrophic feedback loop where fires in older forests create ecologically beneficial snag forests, those forests are then clearcut and replanted with small trees in dense rows lacking structural complexity, only to burn in higher intensities and so on (see figure below)[17],[18]. Legacy trees removed by logging operations anchor soils, provide shade for developing seedlings, "nurse logs" for new growth and soil moisture retention for amphibians and invertebrates, habitat for aquatic species when snags fall into streams, and they store vast amounts of carbon as they slowly (decades to centuries) decompose. The scientific community is generally at consensus with regard to post-fire logging as damaging to ecosystems[19], particularly to spotted owl habitat[20].



Fire in a mature forest produces complex early seral (snag) forest that connects the stages of forest development through time. This cycle is interrupted by post-fire logging and tree planting leading to type conversions (native forest to flammable plantation) and unnatural fire severity.

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[17] Odion, D.C., et al. 2004. Ibid. Thompson, J.R., et al. 2007. Reburn severity in managed and unmanaged vegetation in a large wildfire. PNAS 104:10743-10748.
[18] Bradley, C.M., et al. 2016. Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western United States? Ecosphere 7:1-13.
[19] Lindenmayer, D.B., P.J. Burton, and J.F. Franklin. 2008. Salvage logging and its ecological consequences. Island Press: Washington, D.C.
[20] C.T. Hanson, M.L. Bond, and D.E. Lee. 2018. Effects of post-fire logging on California spotted owl occupancy. Nature Conservation 24:93-105.

Areas of Disagreement

In contrast to post-fire logging, thinning involves partial logging of trees for various purposes, including reducing competition among nearby trees, increasing tree vigor, and accelerating tree growth (e.g., in wet forests it is commonly used to accelerate development of older forest conditions as specified under the Northwest Forest Plan). Thinning also is commonly used to reduce "fuels" in dry forests and has support in the scientific community and with NGOs. When done properly, thinning of small trees followed by prescribed burning[14], or prescribed burning alone in some cases[21], can reduce fire intensity. However, it remains controversial, has significant ecological consequences (short and long-term), and substantial limitations given high costs and the massive scale believed needed to influence fire behavior especially in a changing climate (Box 1).

Large trees (dbh inches marked on trees) marked for removal on a BLM "fuels" project, southwest Oregon (L. Ruediger).

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[21] Zachmann, L.J., D.W.H. Shaw, and B.G. Dickson. 2018. Prescribed fire and natural recovery produce similar long-term patterns of change in forest structure in the Lake Tahoe basin, California. Forest Ecol. & Manage. 409:276-287

Box 1. General limitations of thinning (and collateral ecosystem damages)

(1) Thinning reduces habitat for canopy dependent species, including spotted owls[22], requires an expansive road network damaging to aquatics, can spread invasive and flammable weeds, and, when implemented over large landscapes, releases more carbon emissions than fires, even severe ones[23].

(2) There is a very low probability (3-8%) that a thinned forest will encounter a fire during the narrow period (10-20 years depending on site factors) of reduced "fuels" [24], resulting in large-scale thinning proposals that alter forest conditions over large areas[6].

(3) Excessive thinning (e.g., reducing bulk crown density below 60%) can increase wind speeds and solar radiation to the ground causing increased flammable vegetation growth and fire spread.

(4) Thinning needs to be followed by prescribed fire to reduce flammable slash but this can cause soil damage especially if burning is concentrated in piles (intensifies heat effects.

(5) Thinning is seldom cost effective without public subsidies or removing large fire-resistant trees.

(6) In some regions (Sierra, Klamath-Siskiyou), time since fire is not associated with increasing fire risks (i.e., as forests mature, they become less flammable[25]).

(7) Thinning efficacy is limited under extreme fire weather (principal factor governing large fires).

(8) At regional scales, active management (unspecified forms of logging) have been associated with uncharacteristic levels of high severity fires (see figure below)[26].

[22] Odion, D.C., et al. 2014. Effects of fire and commercial thinning on future habitat of the northern spotted owl. Open Ecology Journal 7:37-51.

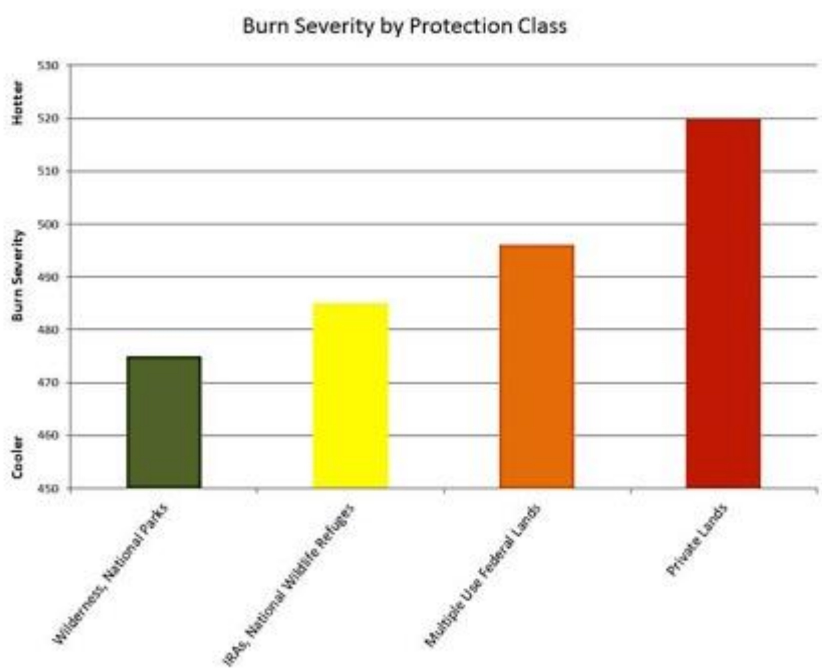
[23] Campbell, J.L., M.E. Harmon, and S.R. Mitchell. 2012. Can fuel-reduction treatments really increase forest carbon storage in western US by reducing future fire emissions? Frontiers in Ecol. & Environ. doi:10.1890/110057

[24] Rhodes, J.J., and W.L. Baker. 2008. Fire probability, fuel treatment effectiveness and ecological tradeoffs. The Open Forest Science Journal, 2008, 1, 1-7

[25] Odion, D.C., et al. 2004. Fire severity patterns and forest management in the Klamath National Forest, northwest California, USA. Conservation Biology 18:927-936. Zachmann, L.J., et al. 2018. Ibid.

[26] Bradley, C.M., C.T. Hanson, and D.A. DellaSala. 2016. Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western United States? Ecosphere 7: Ecosphere 7:1-13.

Thinning on the Deschutes National Forest, Oregon (G. Wuerthner).



Burn severity as a function of protection levels from lower burn severity in Wilderness and National Parks (green) to greater high severity amounts in actively managed areas (red)[26]. Figure prepared by C. Bradley, CBD.

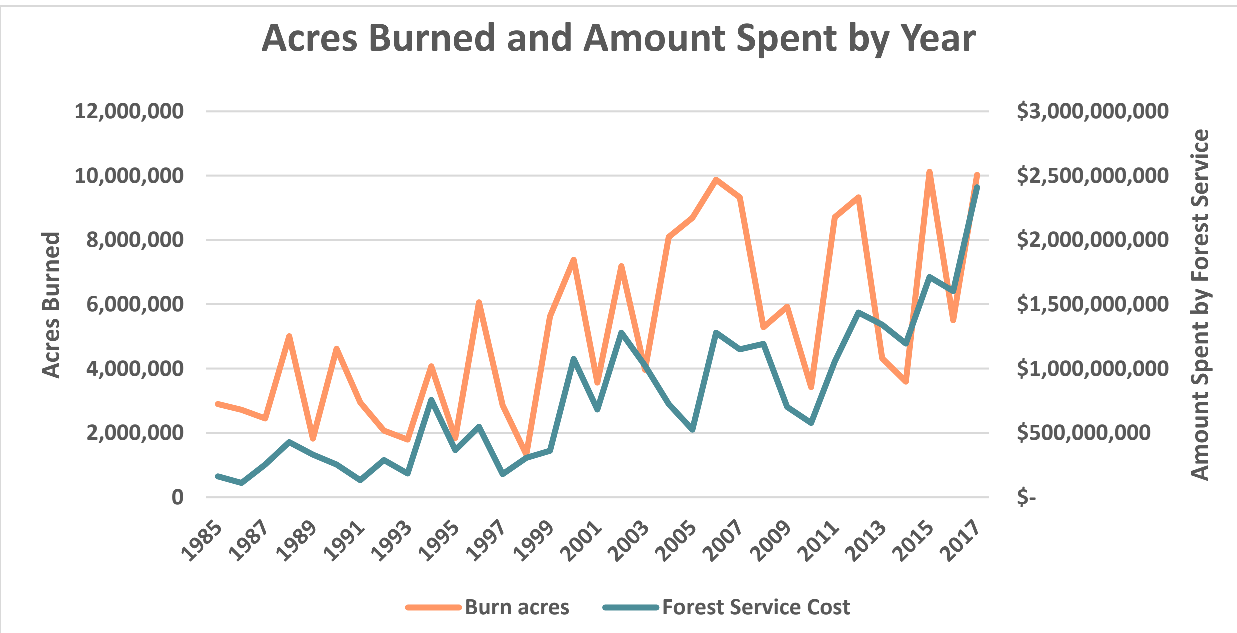
Issue 6: Will More Suppression Spending Make Us Safer?

Background

On March 21, 2018, Congress passed an omnibus spending package that established a dedicated wildfire "disaster" fund of > $2 billion per year that would increase steadily over a 10-year period. Spending measures include expanding the use of controversial categorical exclusions for logging projects up to 3,000 acres each that can conceivably be located adjacent to one another with no regard for cumulative impacts.

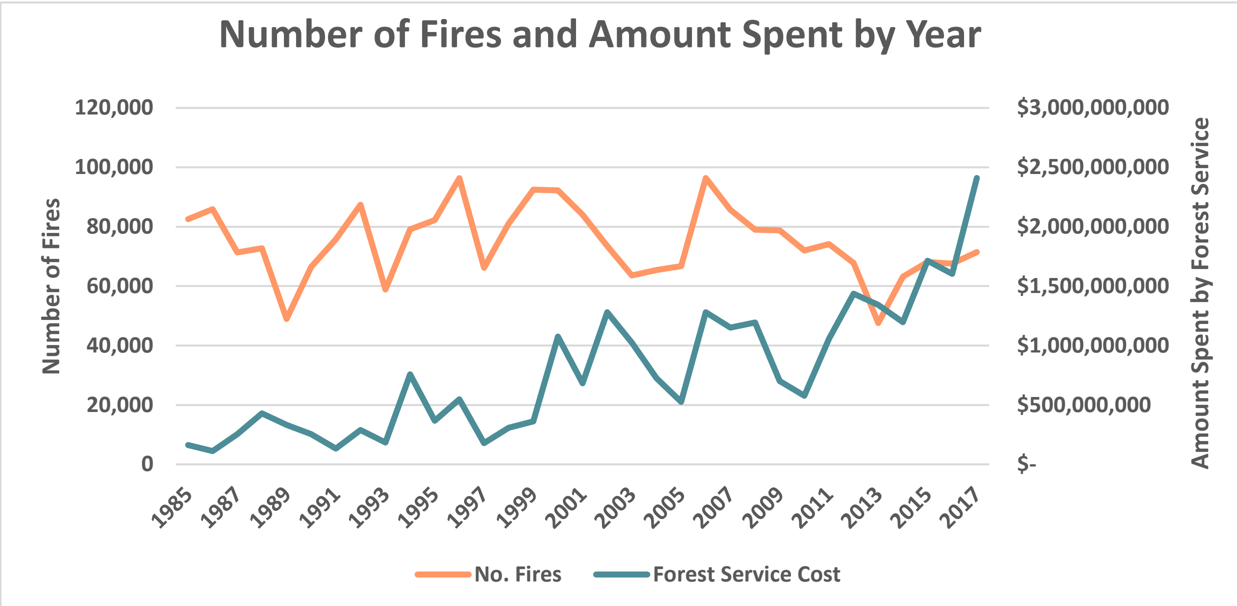
Areas of Agreement and Disagreement (combined)

While conservation groups pushed for a rider-free wildfire spending fix, throwing more money at fire suppression while expecting fewer fires is highly uncertain. In many ways, the two figures below illustrate the common definition of crazy – doing the same thing over and over again but expecting a different outcome. In sum, both acres burning and wildfire suppression costs of the Forest Service have risen dramatically over the past three decades (top figure) calling into question whether more money will achieve fewer fires or less acres burning. Interestingly, in some years (e.g., 2006-2012, bottom figure) total wildfire ignitions steadily dropped while costs generally rose presumably from fighting more fires in remote areas and few controls on spending[27] (figures prepared by J. Leonard, Geos Institute using fire data from National Interagency Fire Center[28]).



[27]Ingalsbee, T., and U. Raja. 2015. The rising cost of wildfire suppression and the case for ecological fire use. Pp. 348-317 In: D.A. DellaSala, C.T. Hanson (eds.). The ecological importance of mixed-severity fires: nature's phoenix. Elsevier: Boston.

[28] https://www.nifc.gov/fireInfo/fireInfo_statistics.html



As an example of unmitigated suppression spending, the 132,127-acre Soberanes fire in California (started by an illegal campfire) cost ~$236 million (nearly $1800 per acre) and deployed thousands of fire fighters and numerous air-tankers, making it the most expensive wildfire to fight in US history. Although the fire destroyed 57 homes (and took the life of a bulldozer operator), suppression forces were used on the fire as it burned safely in the back country far removed from homes. The fire was eventually extinguished by fall rains.

Conclusion: Moving Forward in the New Climate Wildfire Era

When it comes to fire, we each see what we want: land managers view the world as ready-to-burn ecosystems just lacking an ignition source and needing "fuels" reduction; ecologists see habitat restored by wildfires as part of the circle of life and death in a forest; the public fears fire and understandably has concerns about smoke emissions; the media portrays death and destruction during fires; conservation groups are either for or against large-scale thinning; and politicians race to sensationalize fire to justify increased commercial logging on public lands. This is no doubt the most difficult public lands issue we have ever faced as its wrapped in emotion, human health, self-interests, avarice, hyperbole, point-counter point arguments, and nearly everyone wants to do something – even if doing something is worse than the perceived problem. Moving beyond this will require communicating about fire with empathy and clear intent especially while recognizing genuine fear and health issues. It will involve a combination of science publications, public support for managing wildfires for ecosystem benefits (once safety has been addressed), tolerance for temporary smoke levels, and our own limitations in being able to influence ecological processes increasingly governed by top-down drivers (climate) rather than bottom up forest management. Based on climate change models, extreme fire conditions are predicted to be more common this century and thus the extensive thinning involved to theoretically reduce fire intensity (e.g., wide spacing among trees, open-park like conditions) would create novel or greatly engineered forest systems that impact biodiversity and ecosystem services (carbon stores, clean water) in undesirable ways.

Importantly, we need to solve for human safety with the most significant challenges coming from ex-urban sprawl (enabled by scant land-use zoning and building in the wrong places), a rapidly changing climate, an expanding logging footprint focused increasingly on extracting the "new coal" ("feed stock") for biomass burning. Rational fire approaches and communication strategies that do not sacrifice native forests for perceived fire safety are an area of much needed research and financial resources.

We know a lot more about wildfire today than in the last decade; however, much of the science is still in debate, it almost always lags behind or is ignored by decision makers, land managers, and even some scientists and conservation groups with entrenched views about fire (Box 2).

Box 2. What we know and do not know about wildfires.

- ► Complex early seral forests are as biodiverse as old growth, containing comparable levels of species richness (although species composition varies across seral stages).
- ► Wildfire effects on vegetation are highly variable (mixed)[29], calling into question fuel reduction projects (especially those that use a shifting baseline) based on restoring forests to an "historical" open park-like condition when there was a lot more variability and the climate is changing.
- ► It will be impossible to mechanically treat the substantial acres alleged to need fuel reduction to reduce fire intensity[7] (58 million acres according to the Forest Service), and, even if possible, this would have severe consequences to ecosystems, especially aquatics, and come with substantial taxpayer funded costs.
- ► Thinning under extreme fire weather ("the new norm") is highly uncertain in a changing climate.
- ► Additional increases in homes built within the Wildland Urban Interface (WUI) (now totaling 43.4 million)[30] will result in more human-caused fire ignitions and out of control suppression spending regardless of where the money comes from. Wildfire problems will not abate if this growth along with climate change accelerates.

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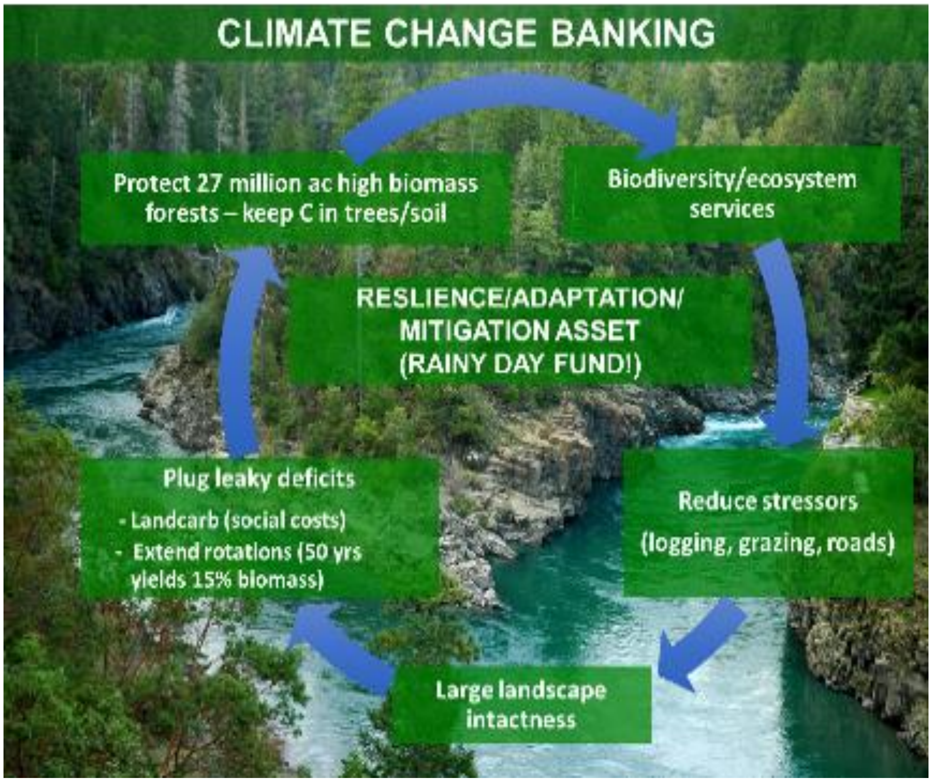
[29]Odion, D.C., et al. 2016. Areas of agreement and disagreement regarding ponderosa pine and mixed conifer forest fire regimes: a dialogue with Stevens et al. PLoSOne DOI:10.1371/journal.pone.0154579 May 19, 2016
[30]Radeloff, V., et al. 2018. Rapid growth of the US wildland -urban interface raises wildfire risk. PNAS http://www.pnas.org/cgi/doi/10.1073/pnas.1718850115

There is no “right” or “wrong” or “good” or “bad” fire. Fire is a predatory force of Nature resulting in ecological winners and losers (at least temporarily). We in the environmental community do not speak of “good” wolves or “bad” mega-wolves (that eat sheep) yet the fire debate embraces this terminology. In sum, we do not have a fire problem per se but rather a people management problem – homes built in the wrong places and with the wrong materials, fire-fighters dropped into unsafe areas, hyped-up thinning projects that may or may not work, and a rapidly changing climate that will produce surprises.

There are plenty of management options that are compatible with western forest resilience and fire-mediated biodiversity in a changing climate, including:

- Removing land-use stressors (e.g., mining, livestock, Off Highway Vehicle impacts that accumulate in space and time) so that ecosystems can adapt to climate change;
- Maintaining viable populations of imperiled species and habitats, including climate sanctuaries such as older forests, forests on north-facing slopes, and riparian areas[31];
- Curtailing the spread of invasive species;
- Managing wildfires for ecosystem benefits and prescribed fire in appropriate types;
- Thinning and girdling (killing) small trees in young plantations (along with prescribed fire) to increase structural complexity and reduce fire intensity (but see limitations discussion);
- Replacing ineffective culverts (especially important in areas where climate change will trigger more floods); restoring floodplains so they can naturally store more water (e.g., reintroducing beavers) and attenuate floods; and removing damaging roads by re-contouring the road prism to natural features (e.g., to reduce sediments to streams and improve hydrological functions);
- Managing for connectivity (up-down elevation, latitudinal-longitudinal gradients); and
- Storing more carbon in forest ecosystems (see climate robust strategies).

[31]Olson, D.M., et al. 2012. Climate change refugia for biodiversity in the Klamath-Siskiyou ecoregion. Natural Areas Journal 32:65-74.

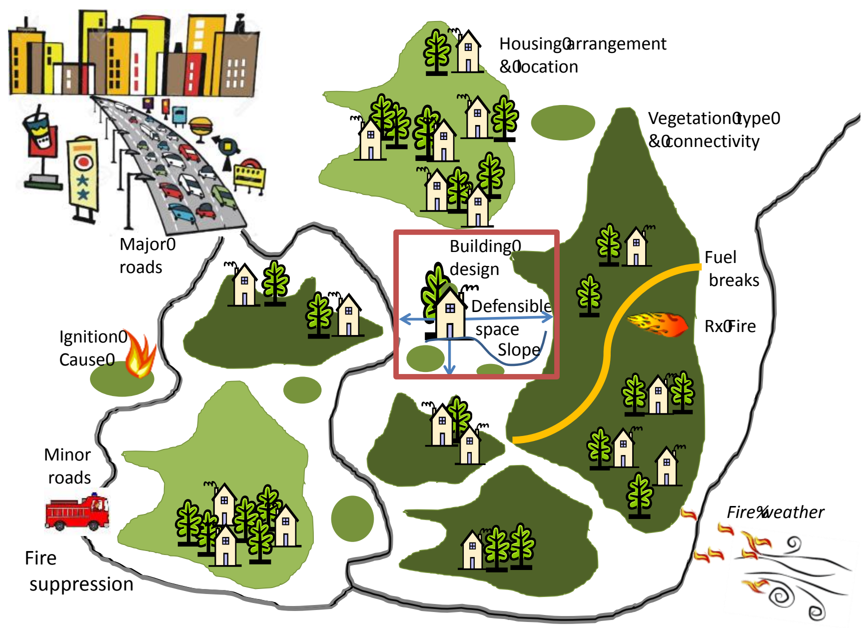


Climate robust conservation means protecting carbon dense forests nationwide as a foundation for biodiversity and ecosystem services, reducing land-use stressors, connecting landscapes for wildlife migrations and reducing carbon emissions from logging. Fire safety measures discussed herein are compatible with this overall strategy and represent a comprehensive path forward.

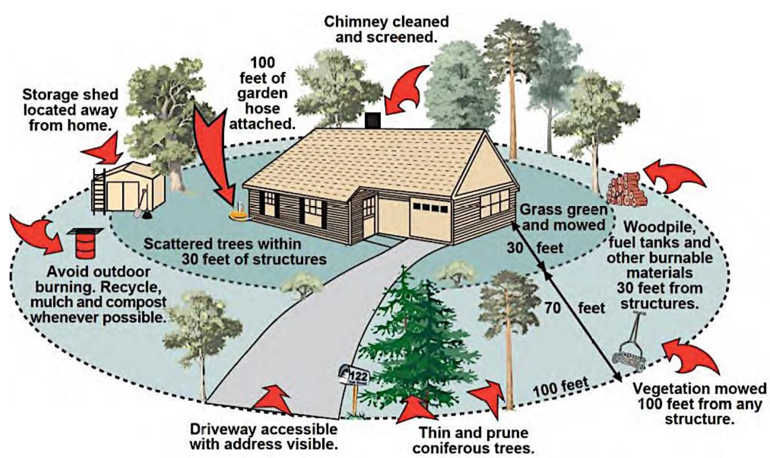
Importantly, managing wildfire for ecosystem benefits is not the same as “let burn.” Instead, this involves monitoring wildfire behavior initially, targeting suppression at fires likely to spread near towns, “loose-herding” and directing fire in the back-country under safe conditions, cutting fire lines nearest homes, and keeping fire fighters out of harm’s way. The same fire can be compartmentalized for different treatments. The Forest Service already has existing authorities that allow them to use such approaches in deciding when to attempt to use suppression vs. managing wildfire for ecosystem benefits[32]. Implementing this policy would help keep spiraling wildfire suppression costs in check[27].

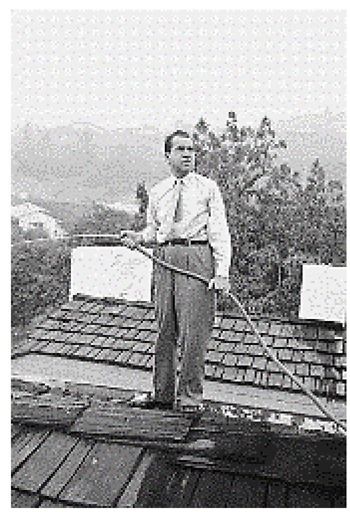
In addition, local governments need to start embracing smart growth measures to limit sprawl within the WUI. Fire safety for existing homes is about reducing risks from the home-out (defensible space), rather than from the wildlands-in (logging)[33]. Defensible space has to become as routine as changing the batteries in a home’s smoke detectors and building with metal roofs the norm in home construction.

[32] https://www.nifc.gov/policies/policies_documents/GIFWFMP.pdf
[33] Syphard, A.D., T.J. Brennan, and J.E. Keeley. 2014. The role of defensible space for residential structure protection during wildfires. Int. J. Wildland Fire. http://www.publish.csiro.au/wf/WF13158



Fire prevention begins with land-use planning that limits growth in unsafe areas and includes defensible space management (figure prepared by A. Syphard, CBI; historical Nixon photo courtesy of San Francisco Chronicle[34]; lower figure – Homeowner fire safe guide for Montana).





Potential synergies and framing messages around forest issues cut across public lands campaigns that could benefit from working together, including the "keep it [carbon] in the ground," "350.org," and a much needed "keep it [carbon] in the forest" campaign. For instance, researchers at Oregon State University recently showed that the best way to increase carbon stores in Northwest forests is to reduce federal lands logging by at least 50%, increase the length of timber harvest rotations on private lands to 80 years, afforestation, and reforestation[35]. Notably, wildfires are currently not a significant contributor to greenhouse gas

[34] http://www.sfgate.com/news/article/Skirball-Fire-recalls-1961-Bel-Air-inferno-that-12410921.php
[35] Law, B.E., et al. 2018. Land use strategies to mitigate climate change in carbon dense temperate forests. PNAS www.pnas.org/cgi/doi/10.1073/pnas.1720064115

emissions, contrary to many assertions[36]. Importantly, the Northwest Forest Plan resulted in ancillary climate benefits by shifting federal forest management from a substantial source of logging emissions in the 1980s to a current "sink" (warehouse) for carbon storage due to reduced (by 80%) timber harvest on federal lands[37]. As this forested warehouse continues to accumulate carbon, it is critical to protect carbon-dense older forests on public lands and incentivize forest carbon stewardship on non-federal lands. Making the link between climate mitigation and intact forest conservation currently lacks the recognition needed to offset fossil fuel emissions and keep the planet from heating above 2° C, which cannot be accomplished without forests in the mix[38].

The long-range prognosis for public lands forests is generally favorable. On the one hand, conservation groups with significant support of the donor community have held the line on decades of hard-fought victories centered on the Northwest Forest Plan and wilderness/ roadless protections. On the other hand, the pressure to develop forests is unprecedented globally and regionally with an urgent need to solve for increasingly complex social, economic, and engrained perceptions about forest management. Conservation science continues to be a leading voice for public lands by supporting effective communications, grass-roots organizing and campaigning, and responding to maladaptive climate policies by proposing climate robust conservation strategies. When it comes to fire science, however, we have as many questions as answers, more debate than consensus, but there have been important strides forward.

In closing, we have much work to do to change public attitudes about forest fires but optimism begins when we open our hearts and minds to the intricate dance between green and burned forest orchestrated by the natural disturbance processes that have been at play since the age of dinosaurs and will continue in largely unpredictable ways in the emerging novel climate. Preparing for these changes must be comprehensive, science-based, and solve for top-down drivers of change while we hold the line and then expand on a robust conservation vision.

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[36]Law, B.E., T.W. Hudiburg, and S. Luyssaert. 2013. Thinning effects on forest productivity: consequences of preserving old forests and mitigating impacts of fire and drought. Plant Ecol & Diversity 6:73-85. Mitchell, S. 2015. Carbon dynamics of mixed- and high-severity wildfires: pyrogenic CO2 emissions, postfire carbon balance, and succession. Pp. 290-312, In D.A. DellaSala, and C.T. Hanson. The ecological importance of mixed-severity fires: nature's phoenix. Elsevier: Boston. Law et al. 2018 (ibid).

[37]Krankina, O.N., M.E. Harmon, F. Schnekenburger, and C.A. Sierra. 2012. Carbon balance on federal forest lands of Western Oregon and Washington: the impact of the Northwest Forest Plan. Forest Ecol. & Manage. 286:171-182

[38]https://primaryforest.org/