Gold Butterfly - Objections

Michael Hoyt
[redacted]

July 25, 2019

Objections related to:

Gold Butterfly Project
Bitterroot National Forest
Responsible Official – Matt Anderson, Forest Supervisor
Located on the east side of the Bitterroot Valley between Burnt Fork and St. Clair Creek encompassing ~55,147 acres

<u>Following are descriptions of specific aspects addressed by this objection.</u>

1. **Landscape Resilience** – "The FS claims that logging/thinning and prescribed burning treatments are required to achieve historical desired conditions, to reduce the impact of wildfires by removing fuels, and to improve the long-term resilience of the forest."

2. **Timber Products and Related Jobs** – "The Organic Administration Act of 1897 establishes that one purpose of the National Forests is to furnish a continuous supply of timber for the use and necessities of citizens of the United States. Additionally, the National Forest Management act of 1976 requires consideration be given to the economic stability of communities whose economies are dependent on National Forest materials.

   "Based on these legal requirements, and on Forest Plan direction, the desired condition is that the Bitterroot National Forest supply the public with forest products on a continual basis and in doing so, contribute to the economic stability of forest-products-dependent communities. The wood products manufacturing industry provides an important service to the rest of the nation, and part of the Forest Service mission is to contribute a sustainable supply of timber."

3. **Chronic Sediment Impact** – "The existing condition is that of higher sediment levels in streams than historic conditions, due to human activities such as road use and recreation. The primary source of sedimentation in the project area is in the lower FS section of Willow Creek, where NFSR (National Forest System Road) 364 parallels the creek for several miles. In some locations, road drainage is not functioning properly and sediment is being delivered into the stream. Poor road drainage increases the risk of catastrophic road failure during high precipitation and runoff events. Risk of failure due to poor road drainage is also an issue in some upper sections of NFSR 364 and NFSR 969 which, although not directly adjacent to a stream, could wash downslope, as occurred in the spring of 2017."

4. **Key Habitat Improvement and Restoration** – "Grassland habitats in the project area were historically a diverse community of bunchgrasses, forbs, and small shrubs. Today, spotted

knapweed is a predominate species in grassland habitats and out-competing native species. Additionally, conifers are spreading into the grasslands. The proposed action targets spotted knapweed and conifer encroachment to improve grassland habitats.

"It is likely that aspen was more prevalent in the project area historically than it is today. The reason is linked to the lack of natural fire on the landscape, discussed above. Aspen is still found on a variety of elevations and aspects, but the stems are generally suppressed by high densities of conifers that have resulted from fire exclusion. The proposed vegetation management would reduce conifer encroachment around aspen stems and clones within treatment units.

"Whitebark pine is a candidate for listing under the Endangered Species Act. In the project area it is being impacted by white pine blister rust, mountain pine beetle, and competition from other conifer species. The proposed action would remove species that are competing with whitebark pine, as well as plant whitebark pine seedlings on suitable sites."

Following are statements which demonstrate a connection between my previous written comments on this project and the content of my objections.

Develop Alternatives

The portions of my original comments to which there was a response were (Comment 2a & 2c):

These proposed actions are based on the assumptions that what historically existed should be "the standard" and that the clock can be turned back. These assumptions discount the effect of a warming climate on natural ecosystems. In addition, they disregard the successional stages of development from grasslands to old growth forest and the different species that inhabit each of the stages.

All treatments in old growth stands should be performed without the use of heavy equipment capable of causing soil compaction.

There is not going to be adequate funding (generated by the project or from other sources) for long-term road maintenance. Therefore, the project should include no new road construction or the reconstruction of decommissioned and/or "undetermined" roads, even though doing so reduces the number of acres that can be "treated;"

You paraphrased my comments to:

- Develop an alternative that only conducts non-commercial thinning in old growth stands, especially outside the Wildland Urban Interface; and

- Develop an alternative that does not re-open 16.5 miles of undetermined roads.

Your responses were:

- (Comment 2a) - Non-commercial thinning in old growth stands was considered but not carried forward as an alternative to analyze as non-commercial thinning would not treat the size class of trees with identified insect and disease concerns in many units. See FEIS Chapter 2, Section 2.3 Alternatives Considered but Eliminated from Detailed Study.

- (Comment 2c) - Vegetation management in old growth stands and construction of new roads were the two primary issues used to develop an alternative to the proposed action (see FEIS Chapter 1, Section 1.8.2) based on external and internal scoping. See FEIS Chapter 2, Section 2.3 Alternatives Considered but Eliminated from Detailed Study.

You sidestepped my points by stating that, "…non-commercial thinning would not treat the size class of trees with identified insect and disease concerns in many units." You clearly state in the FEIS Chapter 1, Section 1.8.2 that, "The IDT determined that in order to facilitate prescribed burning at severities that retain old growth, a reduction in the density of mature (commercial-sized) stems would be required."

By confining your response to tree size, especially "commercial-sized" stems, you evade the widely understood ecological concept that old growth stands are a complex combination of ecosystems which include not only trees, but understory vegetation, insects, arachnids, mammals and other animals, birds, fungi, and microorganisms that live in the soil.

Your failure to provide any answer related to the interrelationship of old growth ecosystems and instead focus on tree size indicates to many observers that the Forest Service continues to focus on logging the most commercially valuable trees possible rather than concentrate on the long-term ecological resilience of forest ecosystems.

<u>The portion of my original comment to which there was a response was (Comment 2e):</u>

> The Economic Analysis of the DEIS includes information (DEIS, Economics Analysis, Table 7) which indicates the Forest Service Estimate for expenditures associated with roads will be ~$325,750. Given that neither "action" alternative offered by the Forest Service will operate in the black, it seems disingenuous to claim that, "The proposed action focuses on improving drainage and implementing Best Management Practices on the main travel routes…" Such a statement could only be truthful if the assumption is made that there are other sources of funds for road maintenance available to the Forest Service.
>
> The claim that existing and new roads involved with this project will be brought up to the required standards or decommissioned (over the long-term) is wishful thinking. All a person has to do is look at the rapidly deteriorating condition of the current roads on the forest for proof that the Forest Service is currently unable to provide adequate care and maintenance. Given the current (and projected) political climate, funding for the Forest Service will not increase. Much more likely are further decreases.
>
> Assuming that a project can operate at a loss and still generate funds for road maintenance is imprudent. Expecting local community members to accept claims that road maintenance will magically improve during and after this project is irrational.

You paraphrased my above comments to:

> Develop an alternative that does not include new road construction.

Your response was:

> Alternative 3 as presented in the FEIS (Chapter 1, Section 1.8.2 Issues Used to Formulate an Alternative) does not propose new road construction.

Your response is not an answer but an evasion of the basis for my contention that:

- The Forest Service has been unable to maintain the existing roads on the forest;
- The project will operate at a loss; and
- Therefore, will be unable to produce funds with which to maintain existing roads let alone new roads.

My unanswered question remains, "Is there another source of funds which will be used to maintain the existing and new roads associated with the Gold Butterfly Project and if not, why does this project add more roads which are unlikely to be maintained?"

Climate Change

The portion of my original comment to which there was a response was (Comment 5g.02):

> Although the section of the DEIS covering climate change discusses carbon cycling and storage, it does not appear to address how the portion of forest included in the Gold Butterfly Project may change due to an increasingly warming climate.

Your response was:

> The Environmental Consequences section in the Climate Change, Forest Carbon Cycling and Storage Specialist Report (PF-CLIMATE-001) discloses potential changes to forest conditions under the no action alternative and both action alternatives.

That response is inadequate. The document to which you refer is not only outdated but copied verbatim from previous projects with the exception of verbiage which references specific projects. An example of project-specific wording is shown by a comparison of the following paragraph from two different projects, the Halfway Malin Project (Idaho Panhandle National Forest – 2016-17) and the Gold Butterfly Project (Stevensville Ranger District – 2017-18).

Halfway Malin Project

> The total carbon stored on the Idaho Panhandle National Forest is approximately 174 Tg, or about thirty-eight one hundredths of one percent (0.0038) of approximately 44,931 Tg of carbon stored in forests of the coterminous U.S. (Heath, et al. 2011). The Halfway Malin Project would affect only a tiny percentage of the forest carbon stock of the Idaho Panhandle National Forest, and an infinitesimal amount of the total forest carbon stock of the United States.

Gold Butterfly Project

> The total carbon stored on the Bitterroot National Forest is approximately 142 Tg, or about thirty-two one hundredths of one percent (0.0032) of approximately 44,931 Tg of carbon stored in forests of the coterminous U.S. (Heath, et al. 2011). The Gold Butterfly Project would affect only a tiny percentage of the forest carbon stock of the Bitterroot National Forest, and an infinitesimal amount of the total forest carbon stock of the United States.

The similarity between the two paragraphs is obvious.

Further proof that the Forest Carbon Cycling and Storage Specialist Report portion of the Gold Butterfly documentation was copied (from a document previously used by the Flathead National Forest) is shown by an oversight in the reference section of the report where project-specific language was inadvertently left unchanged.

The reference in the Gold Butterfly Project documentation reads:

> Harmon et al. (1990) and Harmon (2001) provide general descriptions of the carbon cycle for forests in western Oregon and Washington. These papers make the point that old forests generally store more carbon than younger forests. While we agree with that fact, it is also true that the forests of western Oregon and Washington have disturbance and succession dynamics, and thus carbon dynamics that differ substantially from the Flathead National Forest (pertinent text).

The same reference in the Halfway Malin Project document reads:

> Harmon et al. (1990) and Harmon (2001) provide general descriptions of the carbon cycle for forests in western Oregon and Washington. These papers make the point that old forests generally store more carbon than younger forests. While we agree with that fact, it is also true that the forests of western Oregon and Washington have disturbance and succession dynamics, and thus carbon dynamics that differ substantially from the Idaho Panhandle National Forest (pertinent text).

This proof of boilerplate/template documentation for Forest Service projects is one example of the duplicity of the following claim included in the Gold Butterfly Draft Record of Decision.

> The Gold Butterfly Project environmental impact statement was conducted following the procedures and requirements contained in this Act [NEPA]. An interdisciplinary team (IDT) fully evaluated and disclosed the environmental effects of the proposed project based upon field study, resource inventory and survey, the best available science, and their professional expertise as demonstrated by the contents of the project record. The entirety of the documentation for this decision demonstrates compliance with this Act [NEPA].

That statement clearly states that, "An interdisciplinary team (IDT) fully evaluated and disclosed the environmental effects of the proposed project based upon field study, resource inventory and survey, the best available science, …."

The reference sources cited in the Climate Change, Forest Carbon Cycling and Storage Report do not include research conducted after 2012, a date after which a remarkably large quantity of research contradicts not only the Purpose and Need for the Gold Butterfly Project, but challenges the assumptions made about the project's influence on carbon sequestration and global warming. The lack of recent research would indicate to even the most casual observers that members of the IDT did not use the best available science but instead relied exclusively on previously used, boilerplate templates which cite only older references.

The following statements contained in the Climate Change, Forest Carbon Cycling and Storage Report are further evidence that recent scientific research was ignored.

> This report describes the evidence and rationales why, in this case, we believe additional analysis of this proposal's effects on carbon storage potential, greenhouse gas emissions or climate change are not warranted (page 1).
>
> As discussed further below, meaningful and relevant conclusions on the effects of a relatively minor land management action such as this on global greenhouse gas emissions or global climate change is neither possible nor warranted in this case (page 1).
>
> The proposed actions being considered here may alter the rates and timing of that flux within the individually affected forest stands. These changes would be localized and infinitesimal in relation to the role the world's forests play in ameliorating climate change and indistinguishable from the effects of not taking the action (page 1).
>
> Global climatic warming is not something that is about to happen (page 1).

In contradiction to the claim that "global climate change is not something that is about to happen," NASA estimates Earth has already warmed approximately one degree Celsius (1.8 degrees Fahrenheit) since the late 1800s[1]. Of that, half a degree (around 1.0 degree F) has accrued since 1990 alone. And the 2017 National Climate Assessment again concluded what it has for nearly three decades: Human-made climate change is real, and the impacts have already begun[2].

The Forest Service cannot continue to claim it designs and proposes projects based on the "best available science" while continuing to ignore a contrary consensus by a vast majority of climate scientists. Every project does have an impact on global warming no matter how small. The summation of all Forest Service projects has significantly more than a minute impact on global warming. Focusing on the notion that single projects have an infinitesimal impact on global warming is not only deceptive but allows Forest Service projects to continue contributing to the quickening upward trend in global temperatures, an abhorrent practice at best.

My contention that the Forest Service failed to address how the portion of forest included in the Gold Butterfly Project may (or is likely to) change due to an increasingly warming climate remains unanswered. Citing references which are almost a decade old does not address my contention. Rather it evades the assertion.

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[1] Global Temperature – Latest annual average anomaly:2018 (https://climate.nasa.gov/vital-signs/global-temperature/)

[2] Climate Science Special Report – Fourth National Climate Assessment (NCA4), Volume 1 (https://science2017.globalchange.gov/)

Economic Analysis

The portion of my original comments to which there was a response was (Comment 5h.17):

> In closing, it should be pointed out that a misstatement is contained toward the end of the Economic Analysis portion of the DEIS. Under Unavoidable Adverse Effects, it states "There are no unavoidable adverse effects to the economic impact area." That is simply not true.
>
> The paved and unpaved county-maintained sections of Willow Creek road will experience (over the life of the project) logging truck traffic that will certainly cause disruption to local residents and extensive deterioration of the road surface. Those are economic impacts which are not "unavoidable." The fact is, if the scope of the project is reduced, the number of logging trucks (and related traffic) will be lowered, thereby lessening those specific economic impacts.

You paraphrased that comment to:

> "Clarify the statement 'There are no unavoidable effects to the economic impact area.' under the Unavoidable Adverse Effects section of the DEIS. Reducing the scope of the project would reduce the amount of log truck traffic thereby lessening the economic impact of degrading road conditions on Willow Creek Road."

Your response was:

> This statement could not be found within the environmental document.

The statement which your response claims does not exist is clearly part of the DEIS document, Economic Analysis (near the bottom of page 12) under Unavoidable Adverse Effects.

My contention/question vis-à-vis the DEIS statement that, "There are no unavoidable adverse effects to the economic impact area" remains unaddressed. I would like an explanation for why the Forest Service claims there is no economic impact when one clearly exists.

In the FEIS documentation, I could find no response to the following comment I submitted regarding the DEIS Economic Analysis.

That comment suggested that:

> Since the PNV for this project is negative (DEIS, Economics Analysis, Table 7), a situation which does not stop the project from proceeding, it is clear that log production is of paramount importance. All other stated goals of the project are secondary.

I would like a detailed explanation regarding the validity of the widely held belief—which I unambiguously expressed—that the Gold Butterfly project is a timber project masquerading as a restoration project.

Fire and Fuels

The portion of my original comment to which there was a response was (Comment 5i.05):

> Claims are made that this project will reduce the impact of fires by removing fuels (logging). Studies, including some performed by the Forest Service, indicate that moving combustible materials from a forest may alter the behavior of a naturally occurring fire but it will not eliminate it. (Other than turning a forest into a desert [thereby eliminating all combustible substances], removing only a portion of the flammable materials will not eliminate the possibility of fire.) What it will do is upset the current ecological balance of the forest, a balance in which many trees, other flora, and fauna continue to thrive.

Your response was:

> The Forest Service agrees by reducing the fuels may alter the fire behavior allow for less sever fires. The fuel loading within the Gold Butterfly area would continue to increase under a no treatment, full suppression strategy. This would lead to large area of heavy fuel loadings and increase eh[sic] potential for large fires to develop. Stands would move toward a greater portion of shade tolerant species, which are not adapted to fire. In areas where there had been fuel reductions fire fighters can safely direct attack full suppression fires.

That response does not address the obvious point of my comment which was, "What it [logging, thinning, and prescribed burning] will do is upset the current ecological balance of the forest, a balance in which many trees, other flora, and fauna continue to thrive. Instead, my argument was sidestepped by appearing to agree with the minor point that fuel removal serves to alter fire behavior. Further obfuscating the main point of my comment, your response included distracting information suggesting that an unmanaged forest moves toward more shade-tolerant species and that fuel reductions provide safe havens for fire fighters. You also incorrectly assumed that my comment equates no treatment with a full suppression strategy.

In short my argument that such activities as logging, thinning, and prescribed burns may not increase forest resilience to fire but in fact are more likely to reduce resilience was not only not answered but was ignored. There are numerous recent studies and research projects into the subject of forest resilience in the face of naturally occurring fire which strongly suggest that actively managed forests (logged, thinned, or treated with prescribed burning) are less resilient than those which experience wildfire[3]. A more appropriate answer to my argument would include references to recent research and/or studies which show data contradicting (or agreeing with) my argument.

The continued use of "boilerplate" templates for the DEIS and FEIS clearly indicate that the Forest Service embraces an evaluation of the Gold Butterfly Project which is significantly different from that held by most citizens who are participating in the ongoing project assessment.

A systematic analysis of the publicly available comments from July 2018 indicates the concerns and wishes of the participants. Most are concerned about the establishment of new roads (62%), old growth treatment (56%), the overall effects on wildlife (43%), and project effects on water quality

[3] Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western United States? (https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.1492)

(41%). The attached two graphs (Analysis of GB Comments - July 2018) clearly show the project-related wishes and concerns of the public. Additionally, one graph shows that the majority of those who submitted comments preferred a Modified Alternate 3.

The fact that the Forest Service decided pursue the Agency-preferred Alternate 2 (with very minor adjustments) indicates that the Agency is not collaborating with public participants in a completely open and honest manner. It is also quite clear that the Forest Service continues to act as if its primary job is to "get out the cut," this in spite of the following instructions included in the Multiple-Use Sustained-Yield Act of 1960[4]:

> This Act states that the National Forests are to be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes, and adds that the establishment and maintenance of wilderness areas are consistent with this Act. This Act directs the Secretary to manage renewable surface resources of the National Forests for multiple use and sustained yield of the several products and services obtained therefrom. Multiple use means the management of all the various renewable surface resources of the National Forests in the combination that will best meet the needs of the American people; providing for periodic adjustments in use to conform to changing needs and conditions; and harmonious and coordinated management of the resources without impairment of the productivity of the land. Sustained yield of the several products and services means achieving and maintaining in perpetuity a high-level annual or regular periodic output of renewable resources without impairment of the productivity of the land.

HFRA requires the Forest Service to facilitate collaboration among state and local governments, Indian Tribes and interested persons to encourage meaningful public participation during the preparation of the project.

Definitions of "facilitate" include the expressions "enable" and "make possible." Descriptions for "collaboration" include the words "teamwork" and "cooperation." Explanations of "meaningful" include the term "consequential." In other words, HRFA stipulates the Forest Service must not only enable teamwork between itself and other interested (and effected) parties, the agency must also make "meaningful" cooperation possible. Inclusion of the word "meaningful" in the HFRA was intended to ensure the Forest Service does not simply go through the motions of public comment/objection periods while ignoring contributions. It instructs the Forest Service to use input gathered during those phases to adjust both its priorities and project purposes.

The fact that the Alternative 2 of the FEIS contains insignificant changes from the Alternative 2 in the DEIS, is evidence that the Forest Service is ignoring the intent of HFRA for "real" collaboration and adhering only to the letter of HFRA by "pretending" to collaborate. I find that very discouraging.

A systematic study of the public participants' comments should be conducted with special attention paid to the participants wishes concerning the construction of New Roads, Old Growth treatment, how the project will affect wildlife, and the project's long-term effects on water quality. Then, the Gold Butterfly Project should be reworked to more closely (and honestly) align with the concerns and wishes of the participating public. The current Forest Service claim of "collaboration" is disingenuous at best

[4] https://www.fs.fed.us/emc/nfma/includes/musya60.pdf

Recommendations

- The Agency should learn how to truly collaborate with non-Agency, outside interests.

- The Forest Service should schedule uninterrupted monitoring both during and after implementation of the project. The information gathered from systematic monitoring would provide valuable information which ought to be used during the design and implementation of future projects.

- Projects, such as this, should include either a wider range of alternatives or an easily flexible alternative between "do everything" and "do nothing." Providing only "either or" alternatives merely offers a dichotomy between "good" and "bad," something which, given the current scientific understanding of interconnected ecosystems, is demonstrably deceitful.

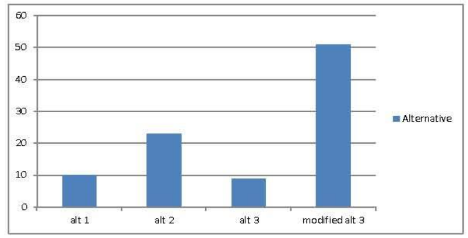
- If Region 1 Headquarters insists that forests under its jurisdiction continue to use boilerplate templates during the preparation of projects, then significant resources must be dedicated to continuously studying and incorporating (into the templates) the most recent scientific studies and research. As it currently stands, those forms currently in use are based upon research which was performed approximately a decade or more in the past. So much new research has been done in the previous few years that contradict Forest Service assumptions upon which projects are based, it is disgraceful. This can and must be rectified.

- The Forest Service should end its practice of calling timber-production ventures, restoration projects. There is currently an overabundance of lumber products in the United States. Continued logging only serves to depress prices and enlarge the oversupply.

- True restoration projects should be the focus of the Agency, the implementation of which help the Nation's forest ecosystems sequester increased amounts of carbon. Continuing to perform "business as usual" is not in the best long-term interest of the environment, the Nation, or its citizens.

Sincerely,

/s/ *Michael Hoyt*



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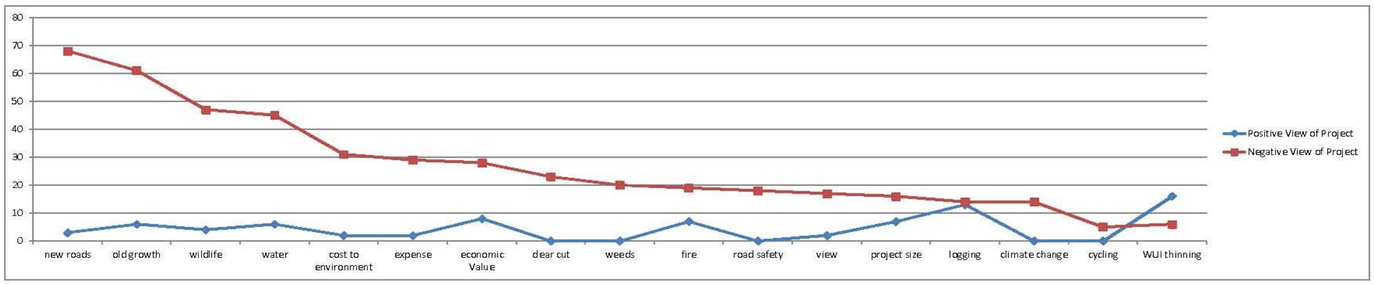

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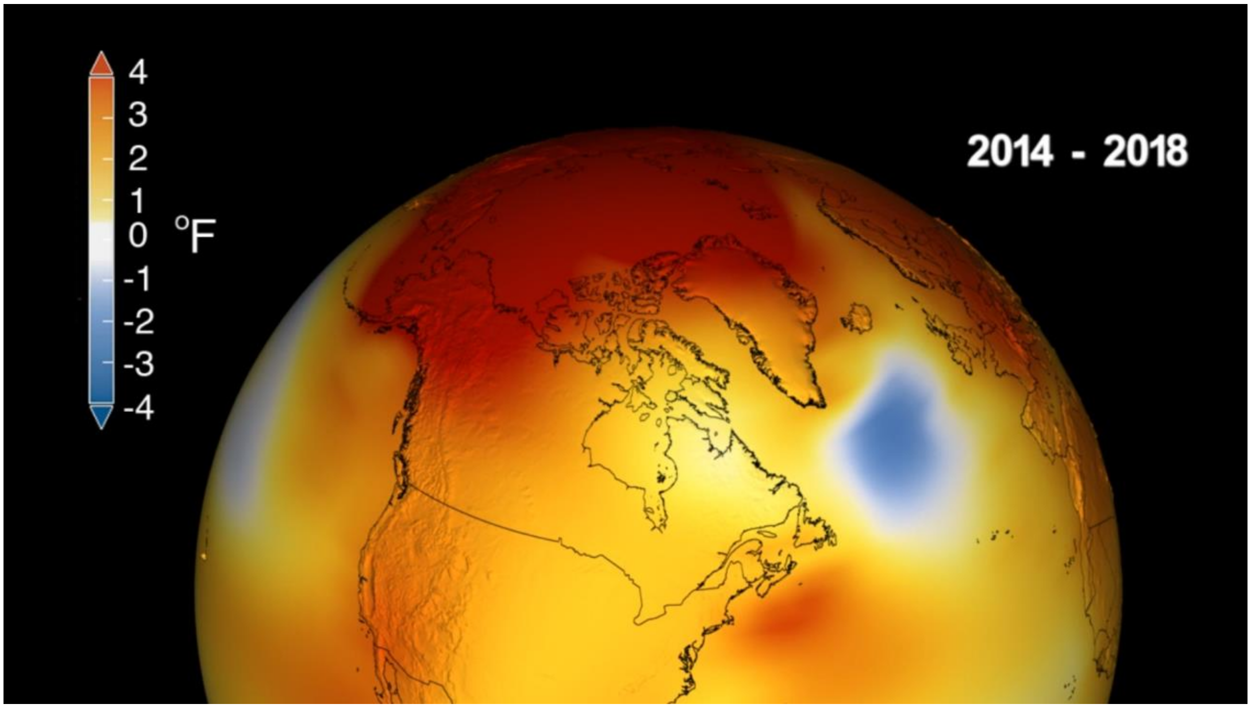
2018 fourth warmest year in continued warming trend, according to NASA, NOAA

February 6, 2019



Earth's global surface temperature in 2018 was the fourth warmest since 1880, according to independent analyses by NASA and the National Oceanic and Atmospheric Administration (NOAA).

Global temperatures in 2018 were 1.5 degrees Fahrenheit (0.83 degrees Celsius) warmer than the 1951 to 1980 mean, according to scientists at NASA’s Goddard Institute for Space Studies (GISS) in New York. Globally, 2018's temperatures rank behind those of 2016, 2017 and 2015. The past five years are, collectively, the warmest years in the modern record.

“2018 is yet again an extremely warm year on top of a long-term global warming trend,” said GISS Director Gavin Schmidt.

Since the 1880s, the average global surface temperature has risen about 2 degrees Fahrenheit (1 degree Celsius). This warming has been driven in large part by increased emissions into the atmosphere of carbon dioxide and other greenhouse gases caused by human activities, according to Schmidt.

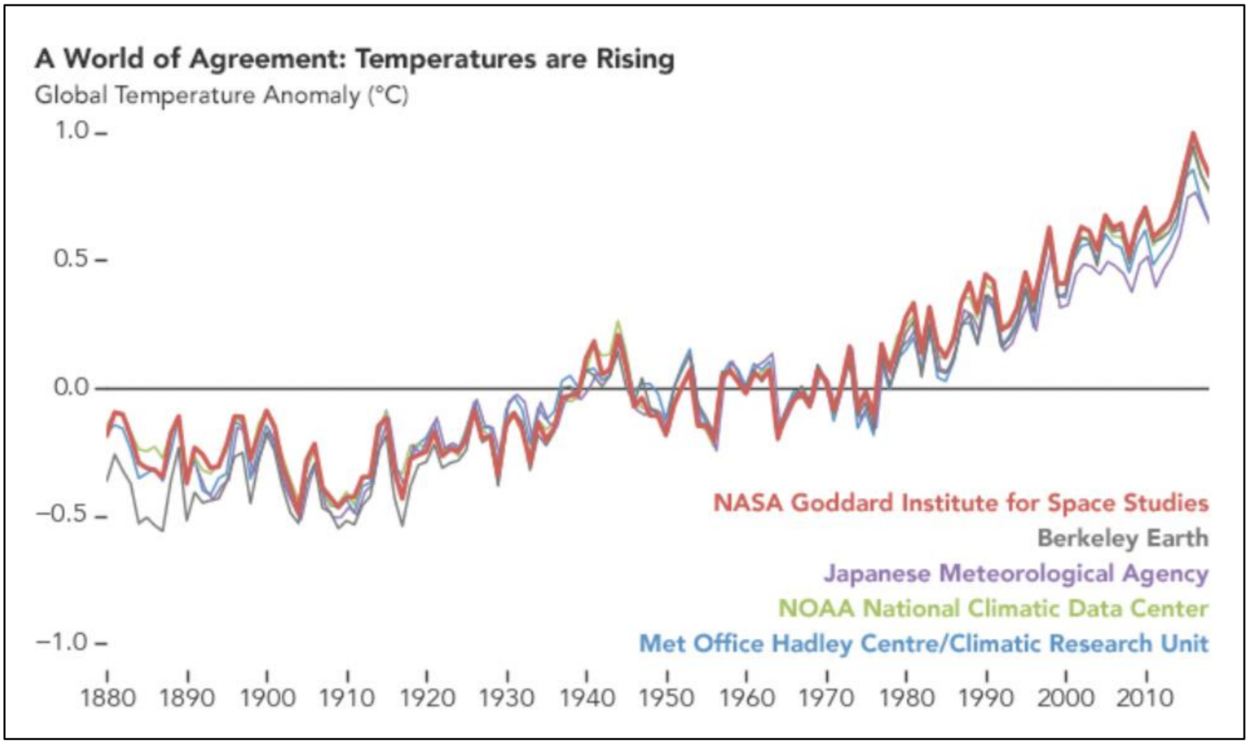
Earth’s long-term warming trend can be seen in this visualization of NASA’s global temperature record, which shows how the planet’s temperatures are changing over time, compared to a baseline average from 1951 to 1980. The record is shown as a running five-year average. Credit: NASA’s Scientific Visualization Studio/Kathryn Mersmann. Download high-definition video and still imagery here.

Weather dynamics often affect regional temperatures, so not every region on Earth experienced similar amounts of warming. NOAA found the 2018 annual mean temperature for the contiguous 48 United States was the 14th warmest on record.

Warming trends are strongest in the Arctic region, where 2018 saw the continued loss of sea ice. In addition, mass loss from the Greenland and Antarctic ice sheets continued to contribute to sea level rise. Increasing temperatures can also contribute to longer fire seasons and some extreme weather events, according to Schmidt.

"The impacts of long-term global warming are already being felt — in coastal flooding, heat waves, intense precipitation and ecosystem change," said Schmidt.

NASA's temperature analyses incorporate surface temperature measurements from 6,300 weather stations, ship- and buoy-based observations of sea surface temperatures, and temperature measurements from Antarctic research stations.



This line plot shows yearly temperature anomalies from 1880 to 2018, with respect to the 1951-1980 mean, as recorded by NASA, NOAA, the Japan Meteorological Agency, the Berkeley Earth research group, and the Met Office Hadley Centre (UK). Though there are minor variations from year to year, all five temperature records show peaks and valleys in sync with each other. All show rapid warming in the past few decades, and all show the past decade has been the warmest. Credit: NASA's Earth Observatory

These raw measurements are analyzed using an algorithm that considers the varied spacing of temperature stations around the globe and urban heat island effects that could skew the conclusions. These calculations produce the global average temperature deviations from the baseline period of 1951 to 1980.

Because weather station locations and measurement practices change over time, the interpretation of specific year-to-year global mean temperature differences has some uncertainties. Taking this into account, NASA estimates that 2018's global mean change is accurate to within 0.1 degree Fahrenheit, with a 95 percent certainty level.

NOAA scientists used much of the same raw temperature data, but with a different baseline period and different interpolation into the Earth's polar and other data poor regions. NOAA's analysis found 2018 global temperatures were 1.42 degrees Fahrenheit (0.79 degrees Celsius) above the 20th century average.

NASA's full 2018 surface temperature data set — and the complete methodology used to make the temperature calculation — are available at:

https://data.giss.nasa.gov/gistemp

GISS is a laboratory within the Earth Sciences Division of NASA's Goddard Space Flight Center in Greenbelt, Maryland. The laboratory is affiliated with Columbia University's Earth Institute and School of Engineering and Applied Science in New York.

NASA uses the unique vantage point of space to better understand Earth as an interconnected system. The agency also uses airborne and ground-based monitoring, and develops new ways to observe and study Earth with long-term data records and computer analysis tools to better see how our planet is changing. NASA shares this knowledge with the global community and works with institutions in the United States and around the world that contribute to understanding and protecting our home planet.

For more information about NASA's Earth science missions, visit:

https://www.nasa.gov/earth

Climate Science Special Report

U.S. Global Change Research Program Climate Science Special Report

Highlights of the U.S. Global Change Research Program

The climate of the United States is strongly connected to the changing global climate. The statements below highlight past, current, and projected climate changes for the United States and the globe.

Global annually averaged surface air temperature has increased by about 1.8°F (1.0°C) over the last 115 years (1901–2016). **This period is now the warmest in the history of modern civilization.** The last few years have also seen record-breaking, climate-related weather extremes, and the last three years have been the warmest years on record for the globe. These trends are expected to continue over climate timescales.

This assessment concludes, based on extensive evidence, that it is extremely likely that **human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century.** For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.

In addition to warming, many other aspects of global climate are changing, primarily in response to human activities. **Thousands of studies conducted by researchers around the world have documented changes in surface, atmospheric, and oceanic temperatures; melting glaciers; diminishing snow cover; shrinking sea ice; rising sea levels; ocean acidification; and increasing atmospheric water vapor.**

For example, **global average sea level has risen by about 7–8 inches since 1900**, with almost half (about 3 inches) of that rise occurring since 1993. Human-caused climate change has made a substantial contribution to this rise since 1900, contributing to a rate of rise that is greater than during any preceding century in at least 2,800 years. Global sea level rise has already affected the United States; **the incidence of daily tidal flooding is accelerating in more than 25 Atlantic and Gulf Coast cities.**

Global average sea levels are expected to continue to rise—by at least several inches in the next 15 years and by 1–4 feet by 2100. A rise of as much as 8 feet by 2100 cannot be ruled out. Sea level rise will be higher than the global average on the East and Gulf Coasts of the United States.

Changes in the characteristics of extreme events are particularly important for human safety, infrastructure, agriculture, water quality and quantity, and natural ecosystems. **Heavy rainfall is increasing in intensity and frequency across the United States and globally and is expected to continue to increase.** The largest observed changes in the United States have occurred in the Northeast.

Heatwaves have become more frequent in the United States since the 1960s, while extreme cold temperatures and cold waves are less frequent. Recent record-setting hot years are projected to become common in the near future for the United States, as annual average temperatures continue to rise. Annual average temperature over the contiguous United States has increased by 1.8°F (1.0°C) for the period 1901–2016; **over the next few decades (2021–2050),**

annual average temperatures are expected to rise by about 2.5°F for the United States, relative to the recent past (average from 1976–2005), under all plausible future climate scenarios.

The incidence of large forest fires in the western United States and Alaska has increased since the early 1980s and is projected to further increase in those regions as the climate changes, with profound changes to regional ecosystems.

Annual trends toward earlier spring melt and reduced snowpack are already affecting water resources in the western United States and these trends are expected to continue. Under higher scenarios, and assuming no change to current water resources management, **chronic, long-duration hydrological drought is increasingly possible before the end of this century**.

The magnitude of climate change beyond the next few decades will depend primarily on the amount of greenhouse gases (especially carbon dioxide) emitted globally. Without major reductions in emissions, the increase in annual average global temperature relative to preindustrial times could reach 9°F (5°C) or more by the end of this century. **With significant reductions in emissions, the increase in annual average global temperature could be limited to 3.6°F (2°C) or less**.

The global atmospheric carbon dioxide (CO2) concentration has now passed 400 parts per million (ppm), a level that last occurred about 3 million years ago, when both global average temperature and sea level were significantly higher than today. Continued growth in CO2 emissions over this century and beyond would lead to an atmospheric concentration not experienced in tens to hundreds of millions of years. There is broad consensus that the further and the faster the Earth system is pushed towards warming, the greater the risk of unanticipated changes and impacts, some of which are potentially large and irreversible.

The observed increase in carbon emissions over the past 15–20 years has been consistent with higher emissions pathways. **In 2014 and 2015, emission growth rates slowed as economic growth became less carbon-intensive**. Even if this slowing trend continues, however, it is not yet at a rate that would limit global average temperature change to well below 3.6°F (2°C) above preindustrial levels.

Executive Summary

New observations and new research have increased our understanding of past, current, and future climate change since the Third U.S. National Climate Assessment (NCA3) was published in May 2014. This Climate Science Special Report (CSSR) is designed to capture that new information and build on the existing body of science in order to summarize the current state of knowledge and provide the scientific foundation for the Fourth National Climate Assessment (NCA4).

Since NCA3, stronger evidence has emerged for continuing, rapid, human-caused warming of the global atmosphere and ocean. This report concludes that "it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence."

The last few years have also seen record-breaking, climate-related weather extremes, the three warmest years on record for the globe, and continued decline in arctic sea ice. These trends are expected to continue in the future over climate (multidecadal) timescales. Significant advances have also been made in our understanding of extreme weather events and how they relate to increasing global temperatures and associated climate changes. Since 1980, the cost of extreme events for the United States has exceeded $1.1 trillion; therefore, better understanding of the frequency and severity of these events in the context of a changing climate is warranted.

Periodically taking stock of the current state of knowledge about climate change and putting new weather extremes, changes in sea ice, increases in ocean temperatures, and ocean acidification into context ensures that rigorous, scientifically-based information is available to inform dialogue and decisions at every level. This climate science report serves as the climate science foundation of the NCA4 and is generally intended for those who have a technical background in climate science. In this Executive Summary, gray boxes present highlights of the main report. These are followed by related points and selected figures providing more scientific details. The summary material on each topic presents the most salient points of chapter findings and therefore represents only a subset of the report's content. For more details, the reader is referred to the individual chapters. This report discusses climate trends and findings at several scales: global, nationwide for the United States, and for ten specific U.S. regions (shown in Figure 1 in the Guide to the Report). A statement of scientific confidence also follows each point in the executive Summary. The confidence scale is described in the Guide to the Report. At the end of the Executive Summary and in Chapter 1: Our Globally Changing Climate, there is also a summary box highlighting the most notable advances and topics since NCA3 and since the 2013 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.

Global and U.S. Temperatures Continue to Rise

Long-term temperature observations are among the most consistent and widespread evidence of a warming planet. Temperature (and, above all, its local averages and extremes) affects agricultural productivity, energy use, human health, water resources, infrastructure, natural ecosystems, and many other essential aspects of society and the natural environment. Recent data add to the weight of evidence for rapid global-scale warming, the dominance of human causes, and the expected continuation of increasing temperatures, including more record-setting extremes. (Ch. 1)

Changes in Observed and Projected Global Temperature

The global, long-term, and unambiguous warming trend has continued during recent years. Since the last National Climate Assessment was published, 2014 became the warmest year on record globally; 2015 surpassed 2014 by a wide margin; and 2016 surpassed 2015. Sixteen of the warmest years on record for the globe occurred in the last 17 years (1998 was the exception). (Ch. 1; Fig. ES.1)

- Global annual average temperature (as calculated from instrumental records over both land and oceans) has increased by more than 1.2°F (0.65°C) for the period 1986–2016 relative to 1901–1960; the linear regression change over the entire period from 1901–2016 is 1.8°F (1.0°C) (very high confidence; Fig. ES.1). Longer-term climate records over past centuries and millennia indicate that average temperatures in recent decades over much of the world have been much higher, and have risen faster during this time period than at any time in the past 1,700 years or more, the time period for which the global distribution of surface temperatures can be reconstructed (high confidence). (Ch. 1)

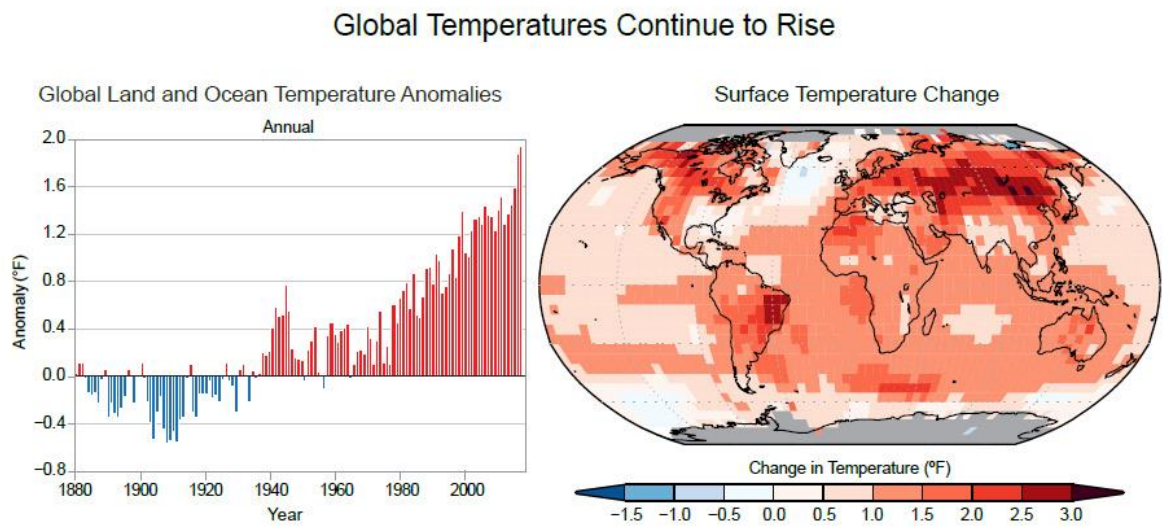


Figure ES.1: (left) Global annual average temperature has increased by more than 1.2°F (0.7°C) for the period 1986–2016 relative to 1901–1960. Red bars show temperatures that were above the 1901–1960 average, and blue bars indicate temperatures below the average. (right) Surface temperature change (in °F) for the period 1986–2016 relative to 1901–1960. Gray indicates missing data. *From Figures 1.2. and 1.3 in Chapter 1.*

- Many lines of evidence demonstrate that it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century. Over the last century, there are no convincing alternative explanations supported by the extent of the observational evidence. Solar output changes and internal natural variability can only contribute marginally to the observed changes in climate over the last century, and there is no convincing evidence for natural cycles in the observational record that could explain the observed changes in climate. (Very high confidence) (Ch. 1)
- The likely range of the human contribution to the global mean temperature increase over the period 1951–2010 is 1.1° to 1.4°F (0.6° to 0.8°C), and the central estimate of the observed warming of 1.2°F (0.65°C) lies within this range (high confidence). This translates to a likely human contribution of 92%–123% of the observed 1951–2010 change. The likely contributions of natural forcing and internal variability to global temperature change over that period are minor (high confidence). (Ch. 3; Fig. ES.2)
- Natural variability, including El Niño events and other recurring patterns of ocean–atmosphere interactions, impact temperature and precipitation, especially regionally, over timescales of months to years. The global influence of natural variability, however, is limited to a small fraction of observed climate trends over decades. (Very high confidence) (Ch. 1)

Human Activities Are the Primary Driver of Recent Global Temperature Rise

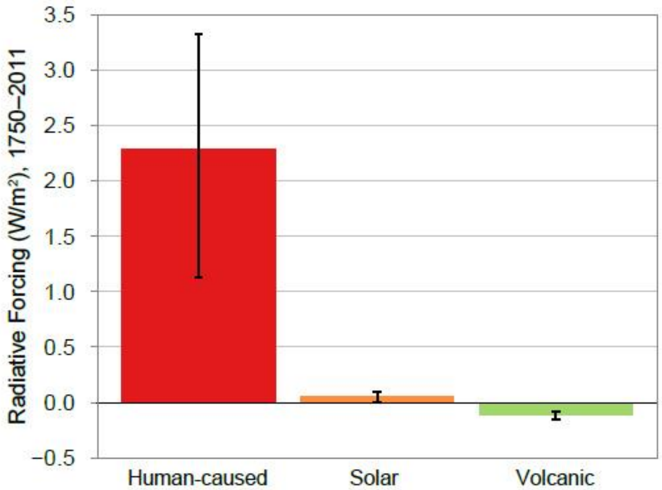


Figure ES.2: Global annual average radiative forcing change from 1750 to 2011 due to human activities, changes in total solar irradiance, and volcanic emissions. Black bars indicate the uncertainty in each. Radiative forcing is a measure of the influence a factor (such as greenhouse gas emissions) has in changing the global balance of incoming and outgoing energy. Radiative forcings greater than zero (positive forcings) produce climate warming; forcings less than zero (negative forcings) produce climate cooling. Over this time period, solar forcing has oscillated on approximately an 11-year cycle between −0.11 and +0.19 W/m^2. Radiative forcing due to volcanic emissions is always negative (cooling) and can be very large immediately following significant eruptions but is short-lived. Over the industrial era, the largest volcanic forcing followed the eruption of Mt. Tambora in 1815 (−11.6 W/m^2). This forcing declined to −4.5 W/m^2 in 1816, and to near-zero by 1820. Forcing due to human activities, in contrast, has becoming increasingly positive (warming) since about 1870, and has grown at an accelerated rate since about 1970. There are also natural variations in temperature and other climate variables which operate on annual to decadal time-scales. This natural variability contributes very little to climate trends over decades and longer. *Simplified from Figure 2.6 in Chapter 2. See Chapter 2 for more details.*

- Global climate is projected to continue to change over this century and beyond. The magnitude of climate change beyond the next few decades will depend primarily on the amount of greenhouse (heat-trapping) gases emitted globally and on the remaining uncertainty in the sensitivity of Earth’s climate to those emissions (very high confidence). With significant reductions in the emissions of greenhouse gases, the global annually averaged temperature rise could be limited to 3.6°F (2°C) or less. Without major reductions in these emissions, the increase in annual average global temperatures relative to preindustrial times could reach 9°F (5°C) or more by the end of this century. (Ch. 1; Fig. ES.3)
- If greenhouse gas concentrations were stabilized at their current level, existing concentrations would commit the world to at least an additional 1.1°F (0.6°C) of warming over this century relative to the last few decades (high confidence in continued warming, medium confidence in amount of warming. (Ch. 4)

This full report can be access online at:

https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf

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ECOSPHERE

Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western United States?

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Citation: 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(10):e01492. 10.1002/ecs2.1492

Abstract. There is a widespread view among land managers and others that the protected status of many forestlands in the western United States corresponds with higher fire severity levels due to historical restrictions on logging that contribute to greater amounts of biomass and fuel loading in less intensively managed areas, particularly after decades of fire suppression. This view has led to recent proposals—both administrative and legislative—to reduce or eliminate forest protections and increase some forms of logging based on the belief that restrictions on active management have increased fire severity. We investigated the relationship between protected status and fire severity using the Random Forests algorithm applied to 1500 fires affecting 9.5 million hectares between 1984 and 2014 in pine (*Pinus ponderosa*, *Pinus jeffreyi*) and mixed-conifer forests of western United States, accounting for key topographic and climate variables. We found forests with higher levels of protection had lower severity values even though they are generally identified as having the highest overall levels of biomass and fuel loading. Our results suggest a need to reconsider current overly simplistic assumptions about the relationship between forest protection and fire severity in fire management and policy.

Key words: biodiversity; climate; fire frequency; fire severity; fire suppression; Gap Analysis Program levels; logging; protected areas.

Received 4 May 2016; revised 28 June 2016; accepted 5 July 2016. Corresponding Editor: Debra P. C. Peters.

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Introduction

It is a widely held assumption among federal land management agencies and others that a lack of active forest management of some federal forestlands—especially within relatively frequent-fire forest types such as ponderosa pine (*Pinus ponderosa*) and mixed conifers—is associated with higher levels of fire severity when wildland fires occur (USDA Forest Service 2004, 2014, 2015, 2016). This prevailing forest/fire management hypothesis assumes that forests with higher levels of protection, and therefore less logging, will burn more intensely due to higher fuel loads and forest density. Recommendations have been made to increase logging as fuel reduction and decrease forest protections before wildland fire can be more extensively reintroduced on the landscape after decades of fire suppression (USDA Forest Service 2004, 2014, 2015, 2016). The concern follows that, in the absence of such a shift in forest management, fires are burning too severely and may adversely affect forest resilience (North et al. 2009, 2015, Stephens et al. 2013, 2015, Hessburg 2016). Nearly every fire season, the United States Congress introduces forest management legislation based on this view and aimed at increasing mechanical fuel treatments via intensive logging and weakened forest protections.

However, the fundamental premise for this fire management strategy has not been rigorously tested across broad regions. We broadly assessed the influence of forest protection levels on fire severity in pine and mixed-conifer forests of the western United States with relatively frequent-fire regimes to test this assumption. We used vegetation burn severity data from all fires >405 ha over a three-decade period, 1984–2014, in forests with varying levels of protection.

Study area

Pine and mixed-conifer forests at low/mid-elevations, where historical fires were relatively frequent, are broadly distributed across several ecoregions in the western United States (Fig. 1; Appendix S1: Table S1). Although ponderosa pine often dominates these forests, they can also include Jeffrey pine (*Pinus jeffreyi*), which in places intermix with, and are similar to, ponderosa pine forests, and Madrean pine–oak (*Quercus* spp.) forests with a diversity of pines. Mixed-conifer forests at low/mid-elevations are also broadly distributed across multiple ecoregions (Fig. 1). They can include additional pines (e.g., lodgepole pine, *Pinus contorta*; sugar pine, *Pinus lambertiana*), true firs (*Abies* spp.), Douglas-fir (*Pseudotsuga menzeisii*), and incense-cedar (*Calocedrus decurrens*).

Methods

We used Gap Analysis Program (GAP) protection classes (USGS 2012), as described below, to determine whether areas with the most protection (i.e., GAP1 and GAP2) had a tendency to burn more severely than areas where intensive management is allowed (i.e., GAP3 and GAP4). We compared satellite-derived burn severity data for 1500 fires affecting 9.5 million hectares from years for which there were available data (1984–2014) among four different forest protection levels (Fig. 1), accounting for variation in topography and climate. We analyzed fires within relatively frequent-fire forest types comprised of pine and mixed-conifer forests mainly because these are the predominant forest types at low to mid-elevations in the western United States, there is a large data set on fire occurrence, and they have been a major concern of land managers for some time due to decades of fire suppression. We defined geographic extent of forest types from the Biophysical Settings data set (BpS) (Rollins 2009; *public communication*, http://www.landfire.gov) that derived forest maps from satellite imagery and represents plant communities based on NatureServe's Ecological Systems classification. Baker (2015) noted that some previous work found ~65% classification accuracy of this system with regard to specific forest types and, accordingly, he analyzed groups of related forest types in order to improve accuracy. We followed his approach (see Appendix S1: Table S1). The categories selected from the Biophysical Settings map were ponderosa/Jeffrey pine and mixed-conifer forest types with relatively frequent-fire regimes (e.g., Swetnam and Baisan 1996, Taylor and Skinner 1998, Schoennagel et al. 2004, Stephens and Collins 2004, Sherriff et al. 2014), compared to other forest types with different fire regimes such as high-elevation forests and many coastal forests not studied herein. Forest types in our study totaled 29.2 million hectares (Fig. 1; Appendix S1: Table S1). We used the BpS data to capture areas that were classified as forests before fire, because postfire vegetation maps can potentially show these same areas as temporarily changed to other vegetation types. We sampled our response and predictor variables on an evenly spaced 90 × 90 m grid within these forest types using ArcMap 10.3 (ESRI 2014). This created a data set of 5,580,435 independent observations from which we drew our random samples to create our models. The 90-m spacing was chosen because it was the smallest spacing of points that was computationally practical with which to operate.

Fires

The Monitoring Trends in Burn Severity project (MTBS, *public communication*, http://www.mtbs.gov) is a U.S. Department of Interior and Department of Agriculture-sponsored program that has compiled burn severity data from satellite imagery, which became available in 1984, for fires >405 ha, and was current up to 2014 (Eidenshink et al. 2007). The MTBS Web site allows bulk download of spatial products that include two closely related indices of burn severity: differenced normalized burn ratio (dNBR) (Key and Benson 2006) and relative differenced normalized burn ratio (RdNBR) (Miller and Thode 2007). Both indices are calculated from Landsat TM and ETM satellite imagery of reflected light from the earth's surface at infrared wavelengths from before and after fire to

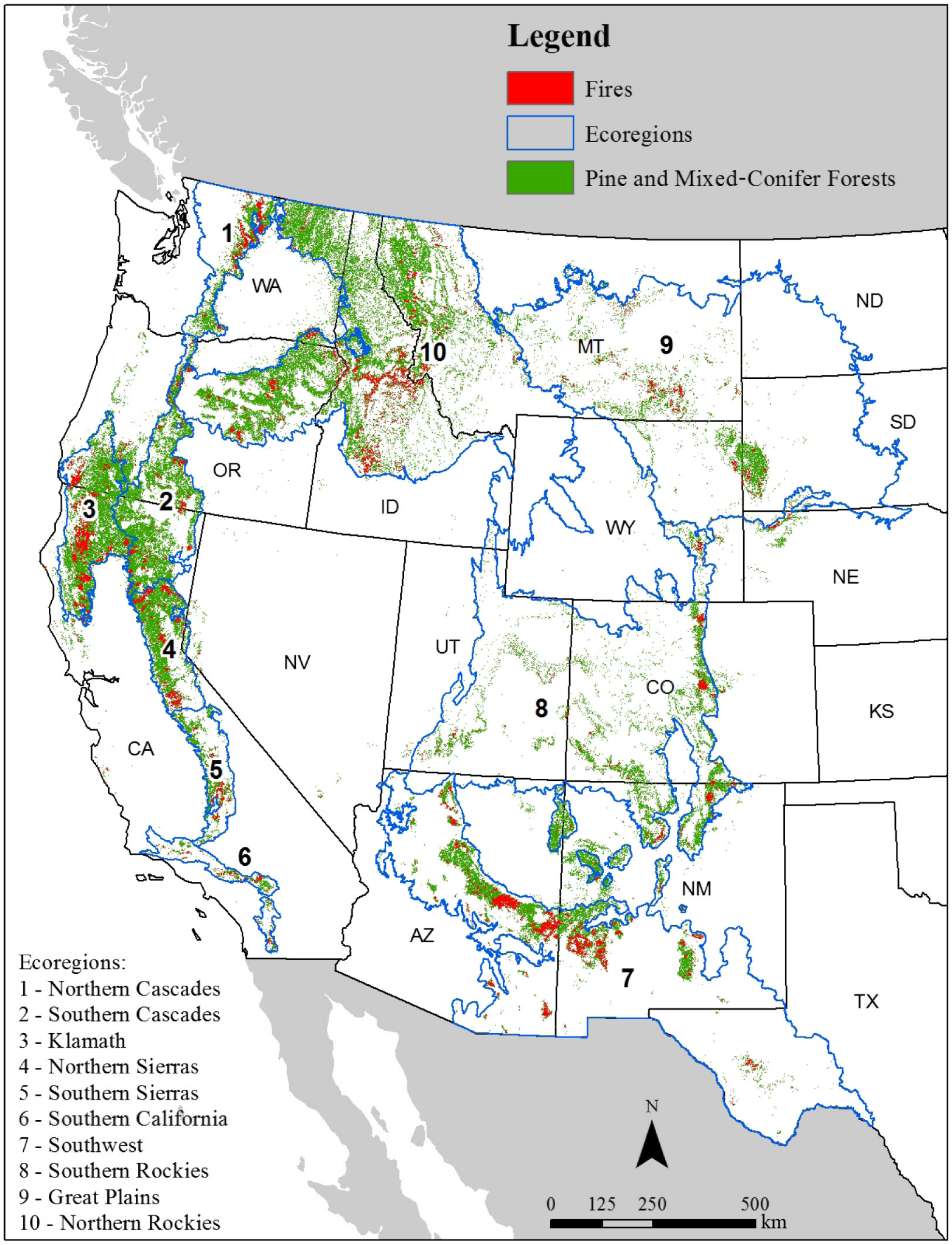

Fig. 1. Pine and mixed-conifer forests, fires, and ecoregions analyzed in this study.

measure associated changes in vegetation cover and soil characteristics. We defined burn severity with the RdNBR index because it adjusts for prefire conditions at each pixel and provides a more consistent measure of burn severity than dNBR when studying broad geographic regions with many different vegetation types (Miller et al. 2009*a*, Norton et al. 2009). RdNBR values typically range from negative 500 to 1500 with values further away from zero representing greater change from prefire conditions. Negative values represent vegetation growth and positive values increasing levels of overstory vegetation mortality. The RdNBR values could be used to classify fires into discrete burn severity classes of low, medium, and high but this was not performed in our study, as we desired to have a continuous response variable in our models.

We intersected forest sampling points with fire perimeters downloaded from MTBS to determine fires that occurred in our analysis area, and censored fires with <100 sampling points (81 ha). The remaining points represented sampling locations from 2069 fires (Fig. 1). We extracted RdNBR values at each sampling point as our response variable as well as predictor variables that included topography, geography, climate, and GAP status. These sampling points were used to investigate the relationship between forest protection levels and burn severity (Appendix S1: Tables S2 and S3). We chose topographic and climatic variables based on previous studies that quantified the relationship between burn severity, topography, and climate (Dillon et al. 2011, Kane et al. 2015).

Topographic and climatic data

To account for the effects of topographic and climatic variability, we derived several topographic indices (Appendix S1: Table S2) from seamless elevation data (*public communication*, http://www.landfire.gov/topographic.php) downscaled to 90-m^2 spatial resolution due to computational limits when intersecting sampling points. These indices capture categories of topography, including percentage slope, surface complexity, slope position, and several temperature and moisture metrics derived from aspect and slope position. We used the Geomorphometry and Gradient Metrics Toolbox version 2.0 (*public communication*, http://evansmurphy.wix.com/evansspatial) to compute these metrics. We also computed several temperature and precipitation variables (Appendix S1: Table S3) by downloading climatic conditions for each month from 1984 to 2014 from the PRISM climate group (*public communication*, http://prism.oregonstate.edu). Climate grids record precipitation and minimum, mean, and maximum temperature at a 4-km grid scale created by interpolating data from over 10,000 weather stations. To determine the departure from average conditions, we subtracted each climate grid by its 30-yr mean monthly value. These "30-yr Normals" data sets were also downloaded from the PRISM Web site and reflected the mean values from the most recent full decades (1981–2010). We determined mean seasonal values with summer defined as the mean of July, August, and September of the year before a given fire; fall being the mean of October, November, and December of the previous year; winter the mean of January, February, and March of the current year of a given fire; and spring the mean of April, May, and June of the current year.

Protected area status and ecoregion classification

We used the Protected Areas Database of the United States (PAD-US; USGS 2012) to determine forest protection status, which is the U.S. official inventory of protected open space. The PAD-US includes all federal and most State conservation lands and classifies these areas with a GAP ranking code (see map at: http://gis1.usgs.gov/csas/gap/viewer/padus/Map.aspx). The GAP status code (herein referred to interchangeably as GAP class or protection status) is a metric of management to conserve biodiversity with four relative categories. GAP1 is protected lands managed for biodiversity where disturbance events (e.g., fires) are generally allowed to proceed naturally. These lands include national parks, wilderness areas, and national wildlife refuges. GAP2 is protected lands managed for biodiversity where disturbance events are often suppressed. They include state parks and national monuments, as well as a small number of wilderness areas and national parks with different management from GAP1. GAP3 is lands managed for multiple uses and are subjected to logging. Most of these areas consist of non-wilderness USDA Forest Service and U.S. Department of Interior Bureau of Land Management lands as well as state trust lands. GAP4 is lands with no mandate for protection such as tribal, military, and private lands. GAP status is relevant to the intensity of both current and past managements.

We made one modification to GAP levels by converting Inventoried Roadless Areas (IRAs) from the 2001 Roadless Area Conservation Rule (S_USA.RoadlessArea_2001, *public communication*, http://data.fs.usda.gov/geodata/edw/datasets.php) to GAP2 unless these areas already were defined as GAP1. We considered most IRAs as GAP2 given they are prone to policy changes and because they allow for certain limited types of logging (e.g., removal of predominately small trees for fuel reduction in some circumstances).

However, we note that very little logging has occurred within IRAs since the Roadless Rule, although there occasionally have been proposals to log portions of some IRAs pre- and postfire, and fire suppression often occurs.

We modified level III ecoregions (U.S. Environmental Protection Agency (EPA) 2013) to create areas of similar climate and geography (Fig. 1). We did this by extracting ecoregions and combining adjacent provinces in our study region.

Random Forests analysis

We investigated the relationship between protection status and burn severity using the data-mining algorithm Random Forests (RF) (Breiman 2001) with the "randomForestSRC" add-in package (Ishwaran and Kogalur 2016) in R (R Core Team 2013). This algorithm is an extension of classification and regression trees (CART) (Breiman et al. 1984) that recursively partitions observations into groups based on binary rule splits of the predictor variables. The main advantage of using RF in our study is that it can work with spatially autocorrelated data (Cutler et al. 2007). It can also model complex, nonlinear relationships among variables, makes no assumption of variable distributions (Kane et al. 2015), and produces accurate predictions without overfitting the available data (Breiman 2001).

Our independent observations were a random subset of our 5.5 million points, from which we drew three random samples of 25,000 points each. Each sample consisted of 500 fires randomly selected without replacement from the pool of 2069 fires. Fifty points were then randomly selected within each of the 500 fires. Our dependent variables were all continuous (Appendix S1: Tables S2 and S3) except for the main variable of interest, protected area status, which included the four GAP levels. The three observation samples were used to create three RF model runs, each consisting of 1000 regression trees. We conducted three RF model runs to assess whether our random samples of 25,000 points produced fairly consistent results.

The RF algorithm samples approximately 66% of the data to build the regression trees, and the remaining data are used for validation and to assess variable importance. We used this validation sample to determine the amount of variance explained and variable importance. The algorithm also produces individual variable importance measures by calculating differences in prediction mean-square-error before and after randomly permuting each dependent variable's values. Variable importance is a measure of how much each variable contributes to the model's overall predicative accuracy.

Unlike linear models, RF does not produce regression coefficients to examine how a change in a predictor variable affects the response variable. The analogy to this in RF is the partial dependence plot which is a graphical depiction of how the response will change with a single predictor while averaging out the effects of the other predictors, such as the climatic and topographic variables (Cutler et al. 2007). We used this approach, in addition to using RF to determine overall variable importance as described above, in order to determine the effect of GAP status, in particular, on fire severity, while averaging out effects of climate and topography.

Mixed-effects analysis

We performed a linear mixed-effects analysis using the "nlme" add-on package in R (Pinheiro et al. 2015). We used a random intercept model and identified year of fire ($n = 31$) and ecoregion ($n = 10$) as random effects. Similar to our RF models, our independent observations were a random subset of our 5.5 million points but for these models we drew three random samples of 50,000 points each. Each sample consisted of 500 fires randomly selected without replacement, and within each of those fires, 100 points were randomly selected. Our dependent variables were the same used in our RF models, and we log-transformed the non-normal variables of slope, surface roughness, and topographic radiation aspect index. We removed dependent variables that were correlated with each other (Pearson's $r > 0.5$), retaining 21 of 45 candidate dependent variables, and centered these on their means. Model reduction was performed in a stepwise process using bidirectional elimination with Bayesian information criterion selection criterion.

Spatial autocorrelation analysis

Spatial autocorrelation (SA) is the measure of similarity between pairs of observations in relationship to the distance between them. Ecological variables are inherently autocorrelated because

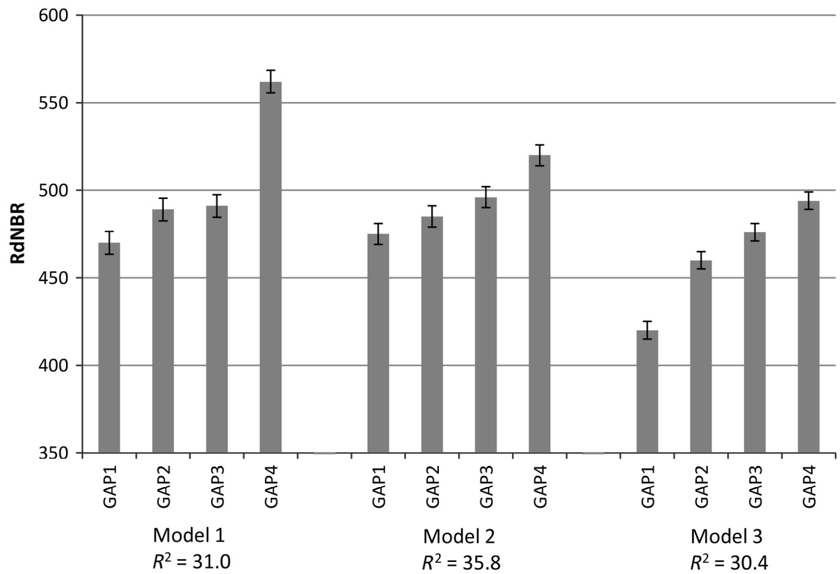

Fig. 2. Random Forests partial dependence of protection status vs. RdNBR burn severity for each model (n = 25,000). The variance explained is shown as pseudo R^2.

landscape attributes that are closer together are often more similar than those that are far apart.

We assessed the SA in the Pearson residuals with inspection of Moran's I autocorrelation index using the "APE" package add-in in R (Paradis et al. 2004) after removing points that shared the same x and y coordinates. Moran's I is an index that ranges from −1 to 1 with the sign of the values indicating strength and direction of SA. Values close to zero are considered to have a random spatial pattern. Our mixed-effects models all had a Moran's I values statistically different from 0 at the 95% confidence level ($P < 0.001$) so we included a spatial correlation structure in our model using the "nlme" package in R. Of Gaussian, exponential, linear, and spherical spatial correlation structures, we determined that the exponential structure produced the lowest Akaike's information criterion (AIC). Despite these additions, our second measurements still found relatively small, but significant, autocorrelation (Moran's I for model runs 1, 2, 3 = 0.10, 0.08, 0.10, all $P < 0.001$).

Results

With regard to ranking of variables in the model runs, variable importance plots from the three RF model runs show that protection status was consistently ranked as one of the 10 most important of the 45 variables in explaining burn severity (Appendix S1: Table S4). The most important variable explaining burn severity was ecoregion for models 1 and 2 and maximum temperature from the previous fall for model 3.

With regard to the GAP status variable in particular, after averaging out the effects of climatic and topographic variables, the RF partial dependence plots show an increasing trend of fire severity with decreasing protection status (Fig. 2). Fires in GAP4 had mean RdNBR values greater than two standard errors higher than all other GAP levels. Fires in GAP3 had mean RdNBR values two standard errors higher than GAP1 in all model runs. GAP3 differences with GAP2 were less pronounced with only one model showing differences greater than two standard errors. Fires in GAP1 were consistently the least severe, being two standard errors less than GAP3 in all model runs and two standard errors less than GAP2 in two of three model runs.

Our mixed-effects models validated these findings with similar results (Fig. 3, Appendix S1: Table S5). Like our RF models, our linear mixed-effects models showed GAP4 fires to have significantly higher RdNBR values and GAP1 fires to have significantly lower RdNBR values when compared to all other GAP classes. Fires in GAP

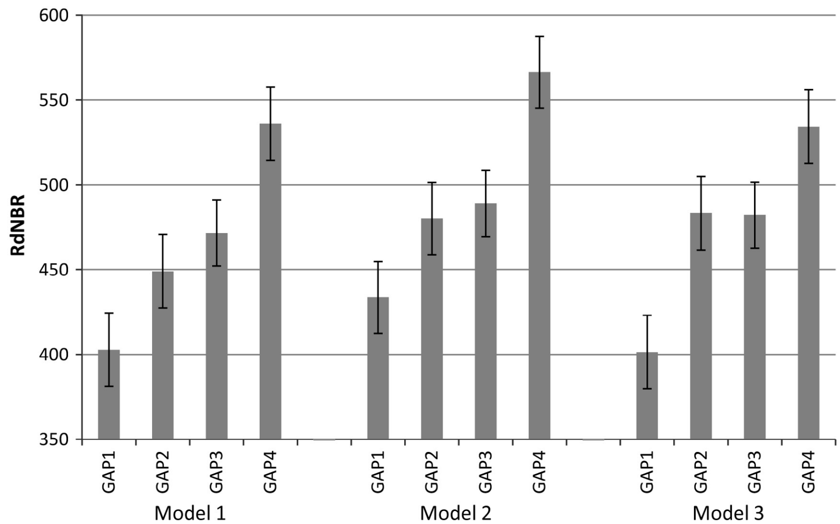

Fig. 3. Linear mixed effects models of protection status vs. RdNBR burn severity (n = 50,000).

status levels 2 and 3 were not significantly different in the mixed-effects models. Although the level of autocorrelation was significant, it was small in our model (Moran's I ~0.1) and not enough to account for such a substantial difference in burn severity among protection classes.

Discussion

Protected forests burn at lower severities

We found no evidence to support the prevailing forest/fire management hypothesis that higher levels of forest protections are associated with more severe fires based on the RF and linear mixed-effects modeling approaches. On the contrary, using over three decades of fire severity data from relatively frequent-fire pine and mixed-conifer forests throughout the western United States, we found support for the opposite conclusion—burn severity tended to be higher in areas with lower levels of protection status (more intense management), after accounting for topographic and climatic conditions in all three model runs. Thus, we rejected the prevailing forest management view that areas with higher protection levels burn most severely during wildfires.

Protection classes are relevant not only to recent or current forest management practices but also to past management. Millions of hectares of land have been protected from logging since the 1964 Wilderness Act and the 2001 Roadless Rule, but these areas are typically categorized as such due to a lack of historical road building and associated logging across patches >2000 ha, while GAP3 lands, for instance, such as National Forests lands under "multiple use management," have generally experienced some form of logging activity over the last 80 yr.

We expect that the effects of historic logging from nearly a century ago to gradually lessen over time, as succession and natural disturbance processes reestablish structural and compositional complexity, but it was beyond the scope of this study to attempt to assess the relative role of recent vs. historical logging. Similarly, industrial fire suppression programs that intensified in the 1940s influenced fire extent across forest protection classes. While more recent let-burn policies have been applied in GAP1 and GAP2 forests in some circumstances, evidence indicates that protected forests nevertheless remain in a substantial fire deficit, relative to the prefire suppression era (Odion et al. 2014, 2016, Parks et al. 2015). Thus, we believe it is unlikely that recent decisions to allow some backcountry fires to burn, largely unimpeded, account for much of the differences in fire severity among protection classes that we found, simply because such let-burn policies have not been extensive enough to remedy the ongoing fire deficit.

While forests in different protection classes can vary in elevation, with protected forests often occupying higher elevations, our results indicate that protection class itself produced notable differences in fire severity after averaging out the effects of elevation and climate (see Fig. 2 and *Results* above). In our study, GAP1 forests were 284 m on average higher in elevation than GAP4 forests, while GAP1 forests experienced lower fire severity. This is the opposite of expectations if elevation was a key influence because higher elevation forests are associated with higher fire severity (see, e.g., Schoennagel et al. 2004, Sherriff et al. 2014). We note that we are not the first to determine that increased fire severity often occurs in forests with an active logging history (Countryman 1956, Odion et al. 2004).

Prevailing forest–fire management perspectives vs. alternative views

An extension of the prevailing forest/fire management hypothesis is that biomass and fuels increase with increasing time after fire (due to suppression), leading to such intense fires that the most long-unburned forests will experience predominantly severe fire behavior (e.g., see USDA Forest Service 2004, Agee and Skinner 2005, Spies et al. 2006, Miller et al. 2009*b*, Miller and Safford 2012, Stephens et al. 2013, Lydersen et al. 2014, Dennison et al. 2014, Hessburg 2016). However, this was not the case for the most long-unburned forests in two ecoregions in which this question has been previously investigated—the Sierra Nevada of California and the Klamath-Siskiyou of northern California and southwest Oregon. In these ecoregions, the most long-unburned forests experienced mostly low/moderate-severity fire (Odion et al. 2004, Odion and Hanson 2006, Miller et al. 2012, van Wagtendonk et al. 2012). Some of these researchers have hypothesized that as forests mature, the overstory canopy results in cooling shade that allows surface fuels to stay moister longer into fire season (Odion and Hanson 2006, 2008). This effect may also lead to a reduction in pyrogenic native shrubs and other understory vegetation that can carry fire, due to insufficient sunlight reaching the understory (Odion et al. 2004, 2010).

Another fundamental assumption is that current fires are becoming too large and severe compared to recent historical time lines (Agee and Skinner 2005, Spies et al. 2006, Miller et al. 2009*b*, Miller and Safford 2012, Stephens et al. 2013, Lydersen et al. 2014, Dennison et al. 2014, Hessburg 2016). However, others have shown that this is not the case for most western forest types. For instance, using the MTBS (www.mtbs.gov) data set, Picotte et al. (2016) found that most vegetation groups in the conterminous United States exhibited no detectable change in area burned or fire severity from 1984 to 2010. Similarly, Hanson et al. (2009) found no increase in rates of high-severity fire from 1984 to 2005 in dry forests within the range of the northern spotted owl (*Strix occidentalis caurina*) based on the MTBS data set. Using reference data and records of high-severity fire, Baker (2015) found no significant upward trends in fire severity from 1984 to 2012 across all dry western forest regions (25.5 million ha), nearly all of which instead were too low or were within the range of historical rates. Parks et al. (2015) modeled area burned as a function of climatic variables in western forests and non-forest types, documenting most forested areas had experienced a fire deficit (observed vs. expected) during 1984 to 2012 that was likely due to fire suppression.

Whether fires are increasing or not depends to a large extent on the baseline chosen for comparisons (i.e., shifting baseline perspective, Whitlock et al. 2015). For instance, using time lines predating the fire suppression era, researchers have documented no significant increases in high-severity fire for dry forests across the West (Williams and Baker 2012*a*, Odion et al. 2014) or for specific regions (Williams and Baker 2012*b*, Sherriff et al. 2014, Tepley and Veblen 2015). Future trends, with climate change and increasing temperatures, may be less simple than previously believed, due to shifts in pyrogenic understory vegetation (Parks et al. 2016).

This is more than just a matter of academic debate, as most forest management policies assume that fire, particularly high-severity fire, is increasing, is in excess of recent historical baselines, and needs to be reduced in size, intensity, and occurrence over large landscapes to prevent widespread ecosystem damages (policy examples include USDA Forest Service 2002, Healthy Forests Restoration Act 2003, USDA Forest Service 2009, HR 167: Wildfire Disaster Funding Act 2015). However, large fires (landscape scale or the so-called megafires) produce myriad ecosystem benefits underappreciated by most land managers and decision-makers (DellaSala and Hanson 2015*a*, DellaSala et al. 2015). High-severity fire patches, in particular, provide a pulse of "biological legacies" (e.g., snags, down logs, and native shrub patches) essential for complex early seral associates (e.g., many bird species) that link seral stages from new forest to old growth (Swanson et al. 2011, Donato et al. 2012, DellaSala et al. 2014, Hanson 2014, 2015, DellaSala and Hanson 2015*a*). Complex early seral forests are most often logged after fire, which, along with aggressive fire suppression, exacerbates their rarity and heightens their conservation importance (Swanson et al. 2011, DellaSala et al. 2014, 2015, Hanson 2014).

Limitations

One limitation of our study is that, due to the coarseness of the management intensity variables that we used (i.e., GAP status), we cannot rule out whether low intensities of management decreased the occurrence of high-severity fire in some circumstances. However, the relationship between forest density/fuel, mechanical fuel treatment, and fire severity is complex. For instance, thinning without subsequent prescribed fire has little effect on fire severity (see Kalies and Yocum Kent 2016) and, in some cases, can increase fire severity (Raymond and Peterson 2005, Ager et al. 2007, Wimberly et al. 2009) and tree mortality (see, e.g., Stephens and Moghaddas 2005, Stephens 2009: Figure 6)—the effects depend on the improbable co-occurrence of reduced fuels (generally a short time line, within a decade or so) and wildfire activity (Rhodes and Baker 2008) and can be over-ridden by extreme fire weather (Bessie and Johnson 1995, Hély et al. 2001, Schoennagel et al. 2004, Lydersen et al. 2014). Empirical data from actual fires also indicate that postfire logging can increase fire severity in reburns (Thompson et al. 2007), despite removal of woody biomass (tree trunks) described by land managers as forest fuels (Peterson et al. 2015). While our study did not specifically test for these effects, such active forest management practices are common on GAP3 and GAP4 lands. Recognizing these limitations, researchers have stressed the need for managers to strive for coexistence with fire by prioritizing fuel reduction nearest homes and allowing more fires to occur unimpeded in the backcountry (Moritz 2014, DellaSala et al. 2015, Dunn and Bailey 2016, Moritz and Knowles 2016).

Follow-up research at finer scales is needed to determine management emphasis and history in relation to fire severity. However, we believe our findings are robust at the subcontinental and ecoregional scales.

Conclusions

In general, our findings—that forests with the highest levels of protection from logging tend to burn least severely—suggest a need for managers and policymakers to rethink current forest and fire management direction, particularly proposals that seek to weaken forest protections or suspend environmental laws ostensibly to facilitate a more extensive and industrial forest–fire management regime. Such approaches would likely achieve the opposite of their intended consequences and would degrade complex early seral forests (DellaSala et al. 2015). We suggest that the results of our study counsel in favor of increased protection for federal forestlands without the concern that this may lead to more severe fires.

Allowing wildfires to burn under safe conditions is an effective restoration tool for achieving landscape heterogeneity and biodiversity conservation objectives in regions where high levels of biodiversity are associated with mixed-intensity fires (i.e., "pyrodiversity begets biodiversity," see DellaSala and Hanson 2015*b*). Managers concerned about fires can close and decommission roads that contribute to human-caused fire ignitions and treat fire-prone tree plantations where fires have been shown to burn uncharacteristically severe (Odion et al. 2004). Prioritizing fuel treatments to flammable vegetation adjacent to homes along with specific measures that reduce fire risks to home structures are precautionary steps for allowing more fires to proceed safely in the backcountry (Moritz 2014, DellaSala et al. 2015, Moritz and Knowles 2016).

Managing for wildfire benefits as we suggest is also consistent with recent national forest policies such as 2012 National Forest Management Act planning rule that emphasizes maintaining and restoring ecological integrity across the national forest system and because complex early forests can only be produced by natural disturbance events not mimicked by mechanical fuel reduction or clear-cut logging (Swanson et al. 2011, DellaSala et al. 2014). Thus, managers wishing to maintain biodiversity in fire-adapted forests should appropriately weigh the benefits of wildfires against the ecological costs of mechanical fuel reduction and fire suppression (Ingalsbee and Raja 2015) and should consider expansion of protected forest areas as a means of maintaining natural ecosystem processes like wildland fire.

Acknowledgments

We would like to thank Monica Bond and Derek Lee for statistical advice and Randi Spivak and Jay Lininger for providing helpful comments on this manuscript. We also thank the reviewers for suggestions, which improved the manuscript.

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Supporting Information

Additional Supporting Information may be found online at: http://onlinelibrary.wiley.com/doi/10.1002/ecs2.1492/full

10. MULTIPLE-USE SUSTAINED-YIELD ACT OF 1960

[As amended through December 31, 1996, P.L. 104–333]

10. MULTIPLE-USE SUSTAINED-YIELD ACT OF 1960 [1]

(Public Law 86–517; Approved June 12, 1960)

AN ACT To authorize and direct that the national forests be managed under principles of multiple use and to produce a sustained yield of products and services, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That ⟦16 U.S.C. 528⟧ it is the policy of the Congress that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes. The purposes of this Act are declared to be supplemental to, but not in derogation of, the purposes for which the national forests were established as set forth in the Act of June 4, 1897 (16 U.S.C. 475). Nothing herein shall be construed as affecting the jurisdiction or responsibilities of the several States with respect to wildlife and fish on the national forests. Nothing herein shall be construed so as to affect the use of administration of the mineral resources of national forest lands or to affect the use or administration of Federal lands not within national forests.

SEC. 2. ⟦16 U.S.C. 529⟧ The Secretary of Agriculture is authorized and directed to develop and administer the renewable surface resources of the national forests for multiple use and sustained yield of the several products and services obtained therefrom. In the administration of the national forests due consideration shall be given to the relative values of the various resources in particular areas. The establishment and maintenance of areas of wilderness are consistent with the purposes and provisions of this Act.

SEC. 3. ⟦16 U.S.C. 530⟧ In the effectuation of this Act the Secretary of Agriculture is authorized to cooperate with interested State and local governmental agencies and others in the development and management of the national forests.

SEC. 4. ⟦16 U.S.C. 531⟧ As used in this Act, the following terms shall have the following meanings:

(a) “Multiple use” means: The management of all the various renewable surface resources of the national forests so that they are utilized in the combination that will best meet the needs of the American people; making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions; that some land will be used for less than all of the resources; and harmonious and

[1] This is the short title of this Act. See section 5.

coordinated management of the various resources, each with the other, without impairment of the productivity of the land, with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output.

(b) "Sustained yield of the several products and services" means the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the national forests without impairment of the productivity of the land.

SEC. 5. [16 U.S.C. 528 note] This Act may be cited as the "Multiple-Use Sustained-Yield Act of 1960".