Wildland Fire, Extreme Weather and Society: Implications of a History of Fire Suppression in California, USA

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Abstract Wildland fire is a natural process integral to the formation and health of forest ecosystems globally. California, USA, is case study where large areas of wildland have a recent 100 plus year history of human suppression of fire that with extreme weather is combining to create large high intensity burns changing both species composition and increasing threats to life, health and property. The cool wet winters and hot dry summers in California produce a climate where fire is common and many environmental systems have evolved to rely on frequent fire for reproduction and health. Fire has been systemically removed creating a backlog of fuels as vegetation normally burned accumulates. Extreme weather enhanced by climate change is increasing the duration of the fire season and occurrence of extreme fire weather and events. The abundance of fuels and increase in probability of fire, primarily due to human-caused ignitions in the wildland–urban interface, are creating an increase of large catastrophic fires not typical of these ecosystems. These large high-intensity fires are an immediate threat to life and property, produce large amounts of smoke impacting human health far from the fire, and leave behind a burn area then susceptible to extreme rainfall events that create landslides and mudslides. Returning fire to the historic role it has played in sustaining these systems reduces the probability of catastrophic fire and the conditions where extreme rainfall can additionally cause further threats to life and property from debris flows. Exposure of the public to smoke from wildfire increases when high intensity burns occur. Wildland fire typical

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of this ecosystem which occurred before suppression limited the extent and amount of such exposure. There are current attempts to effect positive change to policy and give a voice to the role of fire in the ecosystem. Long-standing policy based on the unsustainable complete exclusion of fire and public pressure on air quality inhibits functional change to smoke and fire management. The collision of what current fire and smoke science advises as the appropriate action (inclusion of fire as a land management tool), and public opinion driving implementation of fire management decisions in California (the exclusion of fire) illustrates a global problem where climate change and policy driven by belief are synergistically worsening environmental and human health.

Keywords Wildland fire · Extreme weather · Smoke management policy

1 Introduction

Disturbance from fires is essential to the ecological health of forests and natural areas worldwide (Stephens et al. 2014, pp. 116–117; Thonicke et al. 2008, p. 670). Fuel loading was relatively light in areas where fire was frequent before the era of suppression which has caused multiple fire cycles to be missed and fuels to accumulate. Increases in temperature and drought in others areas, such as the northern Rocky Mountains, USA or the boreal forest biome, with longer intervals between fires are also causing concern because fires are expected to increase in occurrence, area and severity (Gauthier et al. 2015, p. 820).

Fire has an important role to play in the forest ecosystem; however, increased human development of forested areas has reduced the role of fire in the environmental system. Fire is widely suppressed across the world. Suppression is integral to good fire management in a modern world but may undervalue the long-term benefits of this natural disturbance, as well as the social and ecological consequences of the attempted suppression of all fires. Large destructive fires are occurring globally from Mediterranean region including Greece and Portugal to the arctic boreal forests of Canada, Sweden and Russia to the Australian bushfires. Media coverage tells of the destruction of life and property and the devastation of fire when suppression fails. This cycle of using suppression to postpone the occurrence of fire and then reacting to the devastation when suppression does not work with even greater suppression efforts appears to be a policy failure of modern land use because it largely ignores the importance of natural process in forest health and as a mitigation to the effects of climate change.

Extreme weather events and their frequency are a concern globally. How often and where extreme events have been occurring is not uniform spatially (Easterling et al. 2000, p. 417). Where extreme weather combines with an increased fire size and intensity, large high intensity "megafires" can occur. Anthropogenic-driven climatic stressors are contributing to an increase in megafires (Flannigan et al. 2013, pp. 59–60). The negative effects of these fires are heightened by policies and human behavior which lead to increased development susceptible to burning in fire-prone ecosystems (Calkin et al. 2015, pp. 5–6) and extreme levels of fuel loading from active suppression of fire (Steel et al. 2015, pp. 19–20).

Megafire is increasing largely from increased fuel loading and continuity, rising temperatures and longer fire seasons, and increased development within and around fire-prone forests. The 2017 fire season in California, USA, is an excellent example of the conflict between natural process and modern land use and the consequences when suppression fails. The 2017 wildfire season in California was foreseeable with 45 plus years warning of an out of balance fire-prone ecosystem (Kilgore 1973, p. 511) and anthropogenic emissions altering climate. Despite scientific evidence, fire is rarely allowed to burn as it did for millennia. This is particularly true in wilderness areas far from development where the short-term benefits from suppression are largely elimination of smoke.

The use of naturally occurring fire as a management tool along with both suppression and prescribed fire (planned fire with an arranged set of weather and safety conditions to meet burn objectives) each have a role in comprehensive fire management. A question to consider is whether we are accurately valuing the role fire has in the ecosystem for long-term human and ecological health or are we unduly biasing our actions to human intervention. In this chapter, we explore the consequences when suppression policy, or the implementation of the policy, fails and suggest that current air and fire policy and management need substantive change to limit catastrophic, unwanted fire. We discuss the importance of fire as a natural process for forest and human health and how air management policy must recognize that while smoke may be undesirable to the public, it is inevitable and that current air and land management policy actions are contributing to the problem through institutionalized lack of foresight.

2 Fuel Loading and Extreme Weather Influence on Wildland Fire in California, USA

Wildland fire is a natural process with widespread occurrence throughout much of California, affecting natural and cultural resources, human health, infrastructure and public safety. It has a wide range of behavior and effects, which are due to combinations of topography, climate, weather patterns, vegetation types and both natural and human sources of ignition.

The general relationship among fire cycle (years between fires), fire behavior (flame lengths, rate of spread) and vegetation type is called a fire regime. Federally protected land managed for resource objectives include much of the landscape of the American West. Although federal land management agencies (e.g. US Forest Service, National Park Service, Bureau of Land Management, Bureau of Indian Affairs, and the Fish and Wildlife Service) have different founding legislation and missions from resource extraction to conservation, they all are required to minimize the impact of development and use of the land they manage. The agencies additionally have large areas of federal Class I Wilderness Areas (Fig. 1), protected and managed so as to preserve its natural conditions, which are protected by the 1964 Wilderness Act.

This large area of little developed land and wilderness in the western USA embodies the scope of the issue of smoke impacts to populated areas adjacent and dependent on fire-prone areas with fire-adapted species dependent on an active fire regime to remain healthy and unimpaired for future generations. Prior to European settlement

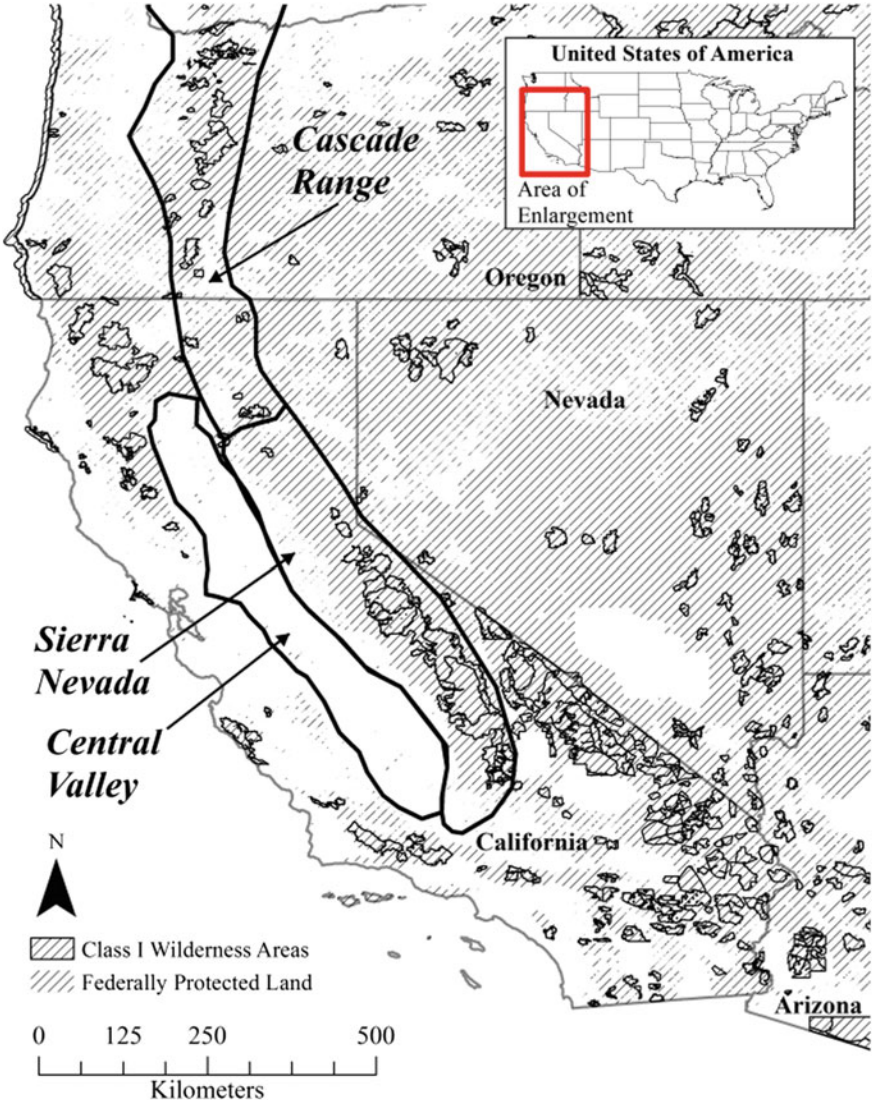

Fig. 1 Wilderness and other federal land management areas in California area, USA

(~1800), stands of mixed conifer forests on the western Sierra Nevada of California (Fig. 1) burned frequently. This fire regime is characterized by low-intensity fires which occurred historically on a cycle of twenty years or less (Sugihara et al. 2006, p. 270). Other vegetation types, such as subalpine forests or coastal chaparral, have fire regimes with longer cycles but can burn more intensely.

Ecosystems tend to be adapted to a specific fire regime. If fire occurs too infrequently, fire regimes with short cycles will be impaired by increasing tree density, an accumulation of fuel, and unnaturally intense fires which often kill mature trees. If fire is too frequent, such as the result of increased human-caused ignitions from arson or carelessness, fire regimes with longer fire cycles will be impaired and over-burn. For example, chaparral can be replaced by invasive grasses if burned too frequently.

Beginning in the early twentieth century, wildfires ignited by human and natural sources begin to be suppressed by local, state and federal fire agencies. While wildfire suppression had occurred before this period, the 1910 wildfires in the Northern Rockies influenced the US Forest Service to approach fire suppression more systematically, and as a cornerstone of its land management policy, which in turn influenced other agencies. The use of fire, such as prescribed fires ignited to produce various post-fire benefits, was also discouraged, although the practice continued in the southeastern USA.

The suppression of wildfires which threaten public safety continues to be an important objective. Protection of life and property is an important component of sound wildland fire management. However, the suppression of all natural fires has significant consequences to forest health and resiliency, especially in areas of California which are characterized by fire regimes with shorter fire cycles, such as the Sierra Nevada and southern Cascades.

Prior to the onset of fire suppression, recently burned areas had reduced quantities of wildland fuels and new, green growth which acted as barriers to fire spread from subsequent ignitions, producing a mosaic of different aged burned areas which could affect and limit the spread of wildfires.

Due to fire suppression, the historic fire mosaic has been lost in many forested ecosystems in the western and southwestern USA. This has been replaced by a layer of continuous wildland fuels which supports the rapid growth of wildfires, especially during wind events. As noted by the California Department of Forestry and Fire Protection (Cal Fire), since accurate records started to be kept in 1932, the top five and seven of the ten largest wildfires in the state have occurred since 2000 (Cal Fire 2018). California fire statistics throughout this chapter only include the last full year of record (2017). It should be noted that 2018, without a complete annual record, already has the largest California wildfire (Mendocino Complex) and the at least 13th deadliest (Carr Fire), suggesting the large destructive wildfires of 2017 were not an anomaly (Fig. 2).

Fire is important to ecological health. Past policies removing fire from the landscape have made these systems susceptible to extreme weather and delayed smoke impacts to the future (Cisneros et al. 2018b, p. 123). Additionally, the changing climate increases fire potential (Liu et al. 2010, pp. 688–691). Extreme weather resulting from climate change is increasing and wildland fire is being affected. Anthropogenic

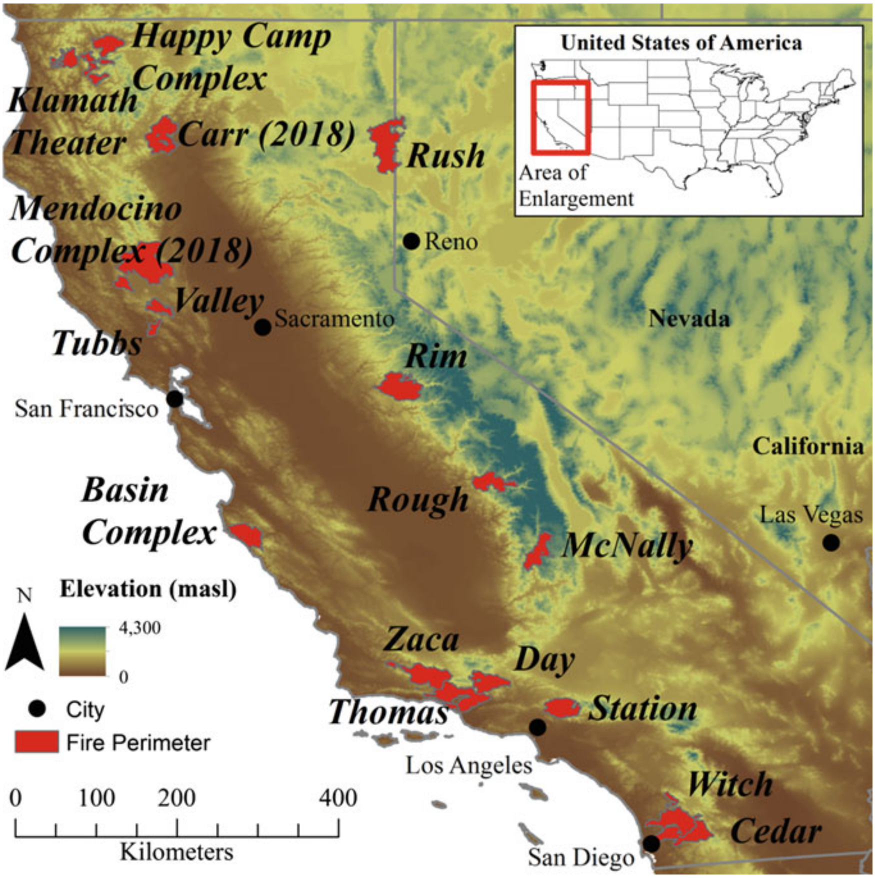

Fig. 2 Significant fires in California since 2002 including the 2018 Carr and Mendocino Complex Fires

emissions are enhancing extreme fire conditions, in which the risk of fire ignition and spread is increasing and fire seasons are being extended (Kirchmeier-Young et al. 2017, pp. 374–376).

More extreme weather and fire conditions are a reality for fire management (Dowdy 2018, p. 233), but fire management strategies and policy are slow to change (North et al. 2015, pp. 1280–1281). Climate and weather impacts to forest fuels provide one metric for early warning and planning of fire management resources (Boer et al. 2017, p. 1201; Littell et al. 2009, pp. 1017–1019). Suppression, a reactive management strategy, is usually the primary tool used by management because the decision process tends to favor the elimination of immediate wildfire risk, with little to no incentive to consider consequences of such decisions that can occur a year or many years in the future. This risk avoidance combined with other factors such as the availability of fire management resources such as engines and aircraft, air quality and public tolerance of smoke, other wildfire activity, etc. creates an environment where there is always a reason not to use fire as a management tool today.

While reactive measures to fire are integral to protect life and property, a healthy forest using proactive fire management for resilience and adaptation is integral to long-term prevention of this loss (Stephens et al. 2018, p. 85). There is an ecological necessity of fire as a natural process for forest health (Hutto et al. 2016, pp. 4–6; Kilgore 1973, pp. 510–511). Species which have evolved in the presence of fire have developed many responses to it, often integrating it into their life cycles. Chaparral species may re-sprout after fire, while some forest species such as knobcone pine (*Pinus attenuata*) and giant sequoia (*Sequoiadendron giganteum*) possess cones which are opened by the heat of a fire, dropping their seeds on nutrient-rich ash. Native grasses such as deergrass (*Muhlenbergia rigens*) are stimulated by fire.

3 US Fire Policy History

Pre-European settlement of the USA, fire was not actively suppressed and was used for resource enhancement. Native Americans were aware of the post-fire responses of many species, and ignited fires to encourage these benefits (Sugihara et al. 2006, p. 272). As settlement increased, suppression became the dominant means to manage fire in the early twentieth century particularly in the western USA. As a result of wildland fire research in the mid-twentieth century, it became apparent that fire suppression as the only management strategy produced long-term negative consequences such as the accumulation of wildland fuels which supported more intense and damaging fires than had occurred during the pre-settlement period.

In the 1970s, federal fire policy changed from one of fire control, in which all wildfires were aggressively suppressed, to one of fire management, which involved a combination of aggressive wildfire suppression and the use of fire for various purposes. This concept of “fire use” could include allowing wildfires to burn for multiple objectives, as well as the execution of prescribed fires ignited by agency staff, for the restoration or maintenance of fire-dependent ecosystems. Fire could also be used to reduce hazardous quantities of wildland fuel, especially near the wildland–urban interface.

The change in federal fire policy has presented land management agencies with a broad spectrum of methods by which public and firefighter safety, property protection and resource management objectives may be pursued. However, wildfire suppression remains the dominant approach, with the protection of safety and property of greatest concern. The use of prescribed and natural fire to restore fire dependent ecosystems which have become impaired by fire suppression, or to meet other management objectives such as wildfire hazard fuel reduction, occurs much less often.

4 Current Conditions: The Backlog of Fire on the Landscape Scale

Nationally, over 4 million hectares of wildfire occurred in 2017 with a federal firefighting cost of 2.9 billion dollars (NIFC 2018). Wildfires during 2015 and 2017 covered the largest area of any years since 1983 with recent prescribed years (2015, 2016 and 2017) also having the largest areas treated (Table 1).

Except for the Bureau of Land Management, the majority of prescribed fire acres occurred in the southeastern USA; the exception was the southwestern USA for the Bureau of Land Management. Generally, wildland fuels in these areas are grassy or brushy, burn more quickly, and produce less smoke than do the heavier forest fuels found in the western USA.

There have been 187 large fires (over 100,000 acres or ~40,000 ha) in the USA since 1997 (NIFC 2018). The largest to burn land in California (32nd largest in the nation 1997–2017) was the 2012 Rush Fire (127,710 ha). The Rush Fire burned in both California (110,039 ha) and Nevada (17,671 ha) and thus the third largest California wildfire ((1) 2017 Thomas 114,078 ha; (2) 2003 Cedar 110,579 ha) to date (Cal Fire 2018). While California has not experienced the largest fires in the USA, the state is fire-prone and densely populated. The year 2017 was a destructive year for fire in California. In 2017, 5 fires in California destroyed 9386 structures and directly caused 40 deaths (Cal Fire 2018).

Table 1 Area burned by wildfire in the USA

Year	Wildfire (ha)	Prescribed (ha)	Total (ha)
2017	4,057,417	2,601,819	6,659,236
2016	2,229,818	1,625,021	3,854,839
2015	4,097,506	1,197,166	5,294,672
2014	1,455,094	967,118	2,422,212
2013	1,748,060	809,388	2,557,448
2012	3,774,198	797,974	4,572,172
2011	3,525,368	855,025	4,380,393
2010	1,385,128	980,903	2,366,032
2009	2,396,464	1,024,306	3,420,770
2008	2,141,788	783,068	2,924,856
2007	3,774,929	1,274,383	5,049,313

From the National Interagency Fire Center fire information statistics (NIFC 2018)

5 Impacts to Life and Property

There are also indirect impacts to life, health and property from wildfire. Table 2 summarizes California fires with the largest losses to life and property (Cal Fire 2018). Loss of life and property can be expected to increase even with advances in firefighting technology and tactics as population increases and fires get larger and more intense. Large loss of life and property can occur on both large and small wildfires. Through 2017, the 19 wildfires covering the largest area in California are all since 1999 and correspond to a period of significant growth of communities into California wildlands. Fire managers are increasingly challenged to suppress larger and more intense wildfires while safeguarding their employees and the public while protecting ever more structures in and adjacent to wildlands.

Burned areas are more vulnerable to erosion and endanger water supplies (Bladon et al. 2014, p. 8939). In addition to ongoing threats to drinking water, extreme rainfall can induce mudslides that directly threaten life and property. For example, the 2017 Thomas Fire, which was the largest recorded California wildfire (until the 2018 Mendocino Complex Fire), was responsible for 1 death (Cal Fire 2018) while the subsequent mudslides after high intensity rains were responsible for over 20 deaths. The Thomas Fire burned north of Los Angeles in Ventura and Santa Barbara Counties in December of 2017 (Fig. 2). Extreme weather including the prolonged Santa Ana winds (strong, dry down-slope winds that flow from inland areas to coastal California) helped spread the fire and, along with the lack of significant recent precipitation, contributed to the large area burned. The fire forced over a hundred thousand residents to be evacuated. Windy, warm and dry weather conditions were then followed by heavy rains starting in early January, 2018, which caused flash floods and mudflows. High-intensity fires increase the potential for debris flows because they remove vegetation that helps hold soil in place and creates a hydrophobic top layer of burned soil (Ren et al. 2011, p. 336). Multiple heavy rain events occurred in this area of southern California from January through July of 2018 with thousands of residents being told to evacuate some multiple times. The extreme weather altering the seasonal timing, extent and severity of the fire followed by extreme rainfall immediately after the fire compounded and extended the disruption to residents of southern California.

Table 2 Selected California wildfires with large loss of life (firefighter and public) and property

Fire	Size (ha)	Year	Deaths	Structures lost
Griffith Park	19	1933	29	0
Tunnel	647	1991	25	2900
Tubbs	14,895	2017	22	5643
Cedar	110,579	2003	15	2820
Rattlesnake	542	1953	15	0
Valley	30,783	2015	4	1955
Witch	80,124	2007	2	1650

It is difficult to capture the impacts of extreme weather and wildfire as it is a complex interaction of the environment with far-reaching effects that can come with the wildfire, the rainy season after, or many years later to ecosystem services such as municipal water supplies. However, increases in extreme weather events amplify the direct impacts to life and property from wildfire.

In order to mitigate the increasing threat of wildfires, the western USA has enormous wildland fuel treatment needs; for example, 3.8 million hectares of forests in Oregon and Washington are in need of prescribed fire and thinning for restoration of conditions which are more resilient to wildfire (Haugo et al. 2015, p. 37). Not all of this area must be treated; as noted by (Finney et al. 2006, p. 125), prescribed fire and other methods of wildland fuels reduction which treat only 10% to 20% of the landscape each decade are effective in disrupting the growth of large wildfires.

Even so, the area treated annually with prescribed fire and wildfire managed for multiple objectives falls far short of the need for such treatments such as for wildland fuel hazard reduction, even as wildfires are becoming larger, more damaging, and expensive. This continuing pattern indicates the discrepancy between the flexible fire policy which supports the use of fire, and the results of the implementation of this policy.

6 Impediments for Beneficial Fire

Air quality regulations, and their application to smoke management, are commonly listed as an impediment to the use of prescribed fire or of wildfire managed for multiple objectives. However, the fire management community also contributes to the treatment shortfall; even if air quality regulators identify conditions under which prescribed fires may be ignited, fire managers may decline the opportunity. For example, while spring weather may have excellent smoke dispersal conditions, fire managers are reluctant to ignite prescribed fires which may continue to burn into the warming and drying summer season, because of a risk that the fire may eventually escape the intended burn unit. Consequently, fire managers prefer to conduct prescribed fires in the fall, when conditions are cooler; however, smoke dispersal is also poorer, and burning permits are more difficult to obtain.

Added to these factors are the frequent occurrence of large wildfires in California in the summer and fall, which cause significant amounts of smoke. Even when such wildfires are not present, there is at least a concern that such fires may occur during this time and will require massive numbers of firefighters to fight, and so there is a reluctance by fire mangers to commit fire staff to prescribed fires and wildfires allowed to burn for multiple objectives and so be unavailable for firefighting if the need arises.

The use of fire will continue to be impaired because the same fire staff charged with short-term fire suppression emergencies is also charged with long-term planning, staffing and management of prescribed fires and wildfires managed for multiple objectives which may cover thousands of hectares and last for several weeks. Area treated will continue to be a fraction of what is needed, and this pattern is unlikely to change unless fire staff is established, dedicated and funded specifically to conduct proactive fire management strategies throughout the fire season.

7 Why not Burn More?

Some ecosystems can benefit from fire suppression, such as chaparral. If burned too often, it can be converted to grassland. However, many California ecosystems are adapted to short fire cycles, and the suppression of fire has caused them to degrade and be more vulnerable to fire. Such forests are dependent on frequent low-intensity fire where smoke will be visible. At the least, wilderness users and rural communities near the fire will be impacted. Smoke will inevitably become a reason to slow down, speed up, or suppress the burn.

Wildfire smoke is arguably the most reviled ecosystem process. While the role wildland fire has in forest and ecosystem health is well studied, the ecosystem role of smoke is not. Limited research has indicated smoke has a role to play in the fire-prone ecosystems of California (Keeley et al. 2005, p. 2320; Klocke et al. 2011, p. 11; Parmeter and Uhrenholdt 1975, p. 31; Thomas et al. 2007, p. 605). Estimations of emissions and area burned in California suggest years that are currently considered extreme fire years are actually more typical of the pre-European settlement period (Stephens et al. 2007, p. 213). The lack of the historic smoke cycle in California may have unintended consequences unrelated to the immediate impacts to human health and comfort. More thoroughly understanding the role smoke plays in the ecosystem will help to further quantify the impacts of fire suppression.

8 Biases and Shortfalls of Smoke Management

Wildfire is inevitable and there are multiple reasons not to burn. But, is smoke perhaps the easiest to remedy? Smoke is in no means the only reason not to burn but it is an important consideration in the anthropogenically polluted airsheds of California. Even though wildland fire smoke has little impact on attainment of air pollution standards (Preisler et al. 2015, p. 347), it is still unpleasant and, for a population that has grown up and through the era of suppression, can be intolerable. In addition, there have been documented adverse health impacts from smoke to the public. Past studies have reported evidence of wildfire smoke being associated with respiratory morbidity, which included exacerbations of symptoms of chronic obstructive pulmonary disease and asthma, and possibly increased mortality from all causes and respiratory infections (Reid et al. 2016, p. 1341).

The policy driving smoke management is a clash of unattainable public wants of a smoke-free environment versus the inevitable smoke from fire. Restricting prescribed and ecologically beneficial fire puts the burden of increased fire risk and smoke exposure onto future generations. Under current policy, air regulators can pass impacts to the future with little or no consequences. The fire next year is rarely attributed to the fire put off today. In addition, fire managers often live in the most smoke impacted areas and often take the brunt of local dissatisfaction. It is easy and convenient to discount the long-term ecological and fire risk impacts of their decisions with regard to the management of natural or prescribed fire where their neighbors are incensed over smoke.

Event management, or documenting the amount and location of smoke and trying to help the public reduce their exposure, is now common on most fires assessing management decisions and is not designed to assess long-term degradation of the environmental system from suppression actions (Schweizer and Cisneros 2017, p. 34). Wildfire smoke, a natural process, is not managed like other naturally occurring emissions such as pollen or volcanic gasses. Culturally, we are biased to believe we can control wildland fire smoke and it is therefore different. Emissions are calculated but unlike anthropogenic emissions have no economic pressure to bypass emission controls and calculations. Wildfire emissions additionally are a much more convenient source to explain air quality. Unlike automobile, agricultural, or industrial emissions which have large financial incentives to err to the lowest amounts or avoid emission controls, naturally occurring wildfire helps these sources most when smoke emissions can be overestimated thereby providing another source for air regulators to focus upon.

Fire management smoke policy is largely dictated by small vocal groups who have an unrealistic belief that all fires can be suppressed (Schweizer and Cisneros 2017, p. 34; Cisneros et al. 2018a, p. 1). But, that is an underestimate of public perception and support. Californians living in and around smoke-prone areas with high levels of anthropogenic pollution have a good understanding of the relative importance of smoke to their overall air quality (Cisneros et al. 2017, p. 5). Nuisance complaints can be an excellent input for fire and air managers but should not be used to determine smoke management (Cisneros and Schweizer 2018, pp. 428–429).

9 A Path to the Future: Using Area Monitoring and Regulatory Thresholds to Assess Smoke Impacts?

While impossible, attempting to eliminate smoke through suppression can help garner support from smoke sensitive groups but ignores both the increased threat to health and safety when suppression fails and the unknown effects to forest ecosystem health in a naturally smoky area. However, current event-driven smoke management is not the solution (Schweizer and Cisneros 2017, p. 34). Model estimates of emissions and atmospheric transport, while important to getting information to the public to reduce smoke exposure, do not accurately reflect the ground-based conditions and without empirical data for exposure are contributing to a false narrative of impacts over time (Cisneros and Schweizer 2018, p. 423; Schweizer and Cisneros 2014, p. 276).

For this reason, there needs to be two distinct independent strategies when managing smoke—(1) event management and (2) proactive smoke management. Event management is needed for a given fire where priority is given to early warning of worse case scenarios. Proactive smoke management needs to consider all potential fires and past impacts and look comparatively at management decisions critically. While event management is widely in place in the USA, proactive smoke management is not. Currently, smoke management is biased to single event analysis or how bad is the smoke in a given location and how adamant is public disapproval.

Smoke from fires burning at historic normal levels of size and intensity can reduce the smoke impacts from other fire types and remain largely below attainment standards (Schweizer and Cisneros 2014, p. 276). Prescribed fire can also limit the impacts through reducing the order of magnitude in size from a large high-intensity fire (Navarro et al. 2018, p. 1). However, any manipulation of a fire that is burning within the historic normal, including the addition of fire during times of good dispersal to allay public smoke exposure concerns, increases smoke exposure (Schweizer et al. 2017, p. 354). Using established air quality standards and thresholds at a landscape level is important for smoke management to be effective (Schweizer et al. 2017, pp. 351–353).

Net smoke exposure seems to be tied fundamentally to the extent of fire management ground actions. Smoke impacts from planned prescribed fire can be beneficial in that the total emissions per day are reduced and meteorological conditions can be chosen while unplanned high intensity forest fires are not. But, for fire in areas such as wilderness where no life or property is at stake, burning at historic timing, size and intensity reduces smoke exposure by limiting dispersal primarily to the less populated area near the fire. This is in contrast with the high plume heights associated with high intensity burns that can impact large urban centers long distances from the fire. Sound smoke management to reduce net exposure needs to favor wildland fires that need little to no fire management action wherever it is safe and possible (e.g. wilderness). Natural process dominated ecosystems will provide the best health outcomes. Favoring a return to natural process fire is integral to sound smoke management policy particularly in the era of increased extreme weather events from climate change. This ideal is not immediately possible because of fuel build-up, increased wildland–urban development and climate change but should be the goal. Particularly in remote wilderness locations, fire that can be left alone should be and fire and air managers along with the public need patience. There is a time and a place for suppression. There is a time and place for prescribed fire. But, there is also a time and place for naturally occurring wildfire to function in the environmental system.

10 Summary and Conclusion

Although many people and organizations are attempting to effect positive change to policy and its implementation and giving a voice to the role of fire in the ecosystem, long-standing policy based on what the public wants, particularly in regards to clean air, inhibits functional change to smoke and fire management. The short-term benefits, including putting off smoke to future generations, belie the narrative that there are no consequences and man's dominion over environmental systems is infallibly beneficial. Management actions largely suppress wildfire while prescribed fire is currently the advocated action by policymakers and implementers. While there is a role for prescribed fire in fire-prone ecosystem restoration, attempting to replace suppression with prescribed fire is largely dealing with the symptoms of fuel buildup and development in the wildland–urban interface. This strategy may allow air and land managers and the public to feel good about reintroducing fire to the system but assumes our process is superior to natural process. Wildland fire smoke from natural process fire takes patience and assumes some of the liability now when it can often be put off.

Extreme weather, climate change, and a history of suppression are combining to limit our ability to defer fire in many areas. Increased wildland fire will come with increased smoke. Smoke can be at the highest exposure levels from megafires when suppression fails (Cisneros et al. 2018b, p. 122). Alternatively, restoring the fire cycle to forests and wilderness far from developed areas may prove the best to reduce adverse health outcomes from smoke exposure and additionally provide forest resiliency to help mitigate loss of life and property from large high-intensity fires more likely under extreme weather events. However, wildland fire smoke in a community comes with a myriad of short-term consequences to public comfort and health. The long-term benefits can easily be disregarded today when we think we can put off the burn to some indefinite future. Suppression also created an artificial expectation of smoke free skies in the American West. Compounded with this unrealistic expectation is the reality that a century of fire suppression has led to an unnatural accumulation of fuels that ultimately will burn producing levels of smoke emissions orders of magnitude larger than occurred before suppression. This "smoke debt" is difficult for a community to accept now because it is more palatable to put it off to some undetermined date in the future. The burden of debt is significant for the current generation, which will have to accept, address and live through the smoke debt when fire occurs and the debt comes due. Deferring both the fuel buildup and smoke debt is a convenient and well-learned behavior developed over many generations in the American West. However, treating these fuels and reducing smoke exposure will not be easier tomorrow.

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