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Key Points:
- Disproportionate scientific focus on recent wildfire trends leads to public misconceptions about wildfire potential in the western United States
- Misconceptions about wildfire underlie a lack of recognition of serious indirect risks wildfires pose to water security
- The scientific community must realign public perspectives and emphasize diverse actions in ecosystem, fire, and water management

Supporting Information:
- Supporting Information S1

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Beyond the 1984 Perspective: Narrow Focus on Modern Wildfire Trends Underestimates Future Risks to Water Security

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Abstract The western United States remains well below historical wildfire activity, yet misconceptions abound in the public and news media that the area burning by wildfire each year in the American West is unprecedented. We submit that short-term records of wildfire and a disproportionate focus on recent fire trends within high-profile science stoke these misconceptions. Furthermore, we highlight serious risks to long-term water security (encompassing water supply, storage, and quality) that have only recently been recognized and are underestimated as the result of skewed perspectives of wildfire. Compiling several data sets, we illustrate a comprehensive history of western wildfire, demonstrate that the majority of western settlement occurred during an artificially and anomalously low period of wildfire in the twentieth century, and discuss the troubling implications the misalignment of wildfire activity and human development may have for the long-term projections of water security. A crucial first step toward realigning public perspectives will require scientists and journalists to present recent increases in wildfire area within the context and scale of longer-term trends. Second, proper housing development and resource management will require an appreciation for the differing western ecosystems and the flexibility to adopt varied approaches. These actions are critical for realigning public understanding of both the direct and indirect risks associated with wildfire and ensuring adequate and appropriate measures are taken as we navigate a future of increasing fire in the West.

Plain Language Summary Area burning by wildfire each year in the western United States has increased rapidly over the past three decades, and news media frequently assert that recent extents of wildfire are *record breaking*. However, research shows that area burning in recent years is a small fraction of what burned prior to the 1920s. Why does this misconception persist and why does it matter? We document that high-profile science articles, frequently cited by the media, disproportionately use data sets that only extend back to 1984. This short-term perspective promotes the false impression that burned areas today are unprecedented. Moreover, this misconception results in the underestimation of serious risks that wildfires pose to long-term water security. High-severity wildfires cause excessive erosion, and with wildfire activity increasing, due to buildup of fuels and increased aridity in the western United States, substantially more sediment can be expected to degrade water quality and reduce water storage capacity in reservoirs throughout the West. Solutions are complex and varied, but despite the known risks, we advocate for allowing more managed (low-severity) wildfire to burn under appropriate conditions, in an effort to reduce potential for high-severity burns and associated erosion, thereby extending the lifespan of reservoirs.

News media frequently report on dramatic increases in wildfire in the western United States, with many headlines claiming wildfire area has reached unprecedented or record levels (e.g., Fears, 2016). Although burned area has increased over the past few decades (Abatzoglou & Williams, 2016; Miller & Safford, 2012; Westerling et al., 2006), the notion that we are witnessing *record breaking* area burned is a fallacy. We contend that widespread public and media misconceptions about wildfire are influenced by a modern temporal bias in available fire records and a disproportionate focus on recent wildfire trends in high-profile science. Those living in the West are thus conditioned to believe artificially low periods of fire during the twentieth century represent the norm, and accordingly, underestimate wildfire risks to infrastructure and water security. Meanwhile, these risks are on the rise as the projected warming and drying of the western states will fuel future increases in wildfire activity (Hawbaker & Zhu, 2012).

A review of *Science*, *Nature*, and *PNAS* reveals that 77% of wildfire-related articles published about the western United States since 2000 ($n = 52$) only address fire trends from the past few decades. In many of these studies, as well as in principal wildfire databases (Eidenshink et al., 2007; National Interagency Fire Center (NIFC), 2017), ca. 1984 is frequently the first year presented, because this marks the beginning of consistent, satellite-derived records (Short, 2015). Wildfire area has rapidly increased since 1984, as ecosystems realize their potential to burn in an era of lengthening fire seasons and warming temperatures (Abatzoglou & Williams, 2016). However, this *1984 perspective* of wildfire is problematic. First and foremost, the 1980s represent the end of an anomalously low period for wildfire during the mid-twentieth century, and western United States landscapes remain well below historical wildfire activity (Barrett et al., 1997; Leenhouts, 1998; Littell et al., 2009; Stephens et al., 2007; Swetnam et al., 2016). While fire scientists are aware of the historical changes in western fuels and fire, it is critical that we better communicate and educate the public about the need and capacity for fire in this region, as well as other regions around the world facing similar challenges (Liu et al., 2010). Understanding the possible scale of future wildfire trends requires looking further into the past.

Historical reconstructions of annual area burned demonstrate that wildfire area in the presettlement western United States was many times greater than the supposed *record highs* of today (Barrett et al., 1997; Leenhouts, 1998; Stephens et al., 2007; Figures 1a and 1c). Borne out by hundreds of fire-history studies, research consistently shows that dry western forests frequently burned by wildfire over the past few centuries (Falk et al., 2010). Although wildfire activity naturally oscillates over millennial timescales (Marlon et al., 2012), area burned across the West began to rapidly decline in the late nineteenth century with the introduction of railroads and livestock (Swetnam et al., 2016). This was especially true in dry forest ecosystems, where livestock ate the fine fuel necessary to carry widespread surface fires. By the mid-twentieth century (ca. 1950s to mid-1980s), the area burning annually across all western ecosystems had plummeted from 7–18 Mha to less than 0.5 Mha due to fire suppression activities (Leenhouts, 1998; Littell et al., 2009; Figure 1a). This West-wide decline in area burned is corroborated by subregional records (Figure 1c) and is consistent with the twentieth century *fire deficit* observed in fire scar and charcoal influx records (Marlon et al., 2012).

The suppression of wildfire was effective for decades due to extraordinary fire-fighting efforts, including the construction of infrastructure (nearly 100,000 miles of forest roads and thousands of fire towers), public service campaigns (e.g., Smokey Bear), and postwar technological advances (e.g., fire retardants and aerial bombing; Pyne, 1982). However, despite budget-busting increases in the resources diverted to suppression over the past three decades (Doerr & Santín, 2016; National Interagency Fire Center (NIFC), 2017; Figure 1b), burned area has increased considerably since 1984 (Eidenshink et al., 2007; National Interagency Fire Center (NIFC), 2017). The annual area burned, as well as burn severity, are projected to continue increasing across the western United States through the 21st century due to climate change and, in some ecosystems, excess fuel loading from fire suppression (Abatzoglou et al., 2017; Abatzoglou & Williams, 2016; Brown et al., 2004; Hawbaker & Zhu, 2012; Westerling et al., 2011).

Although presettlement wildfire activity was much greater than today, the rising trends in fire are now complicated by the explosion of human development that began in the mid-twentieth century during effective fire suppression (Figure 1b). In particular, the establishment of reliable water resources in the 11 western states, along with highways and other critical infrastructure, enabled a greater than fourfold increase in population growth rates starting in the 1940s (Hobbs & Stoops, 2002; U.S. Census Bureau, 1975; U.S. Census Bureau, 2010; Figure 1b). Data collected since 1990 reveal that consistently one third of these western populations live in the wildland urban interface; over 23 million people as of 2010 (Radeloff et al., 2017; Figure 1b). As wildfire risk continues to climb, both insurance companies and property owners have reason for concern. Business and homeowners are faced with prohibitively expensive fire-proofing options (Penman et al., 2017), and there are increasing occurrences of insurer-initiated nonrenewals of coverage (Gabbert, 2017). Nevertheless, people continue to develop in these vulnerable areas.

Another problem that stems from the public's 1984 perspective is a lack of appreciation for indirect risks posed by increases in wildfire. Critically, yet only recently recognized even within the scientific community, wildfire has the potential to cause rapid losses of water supply capacity in reservoirs (e.g., Bladon et al., 2014; Hallema et al., 2018; Martin, 2016; Sankey et al., 2017). More than half of the major dams in the 11 western states were constructed in the four decades following World War II and account for nearly 2/3 of the total

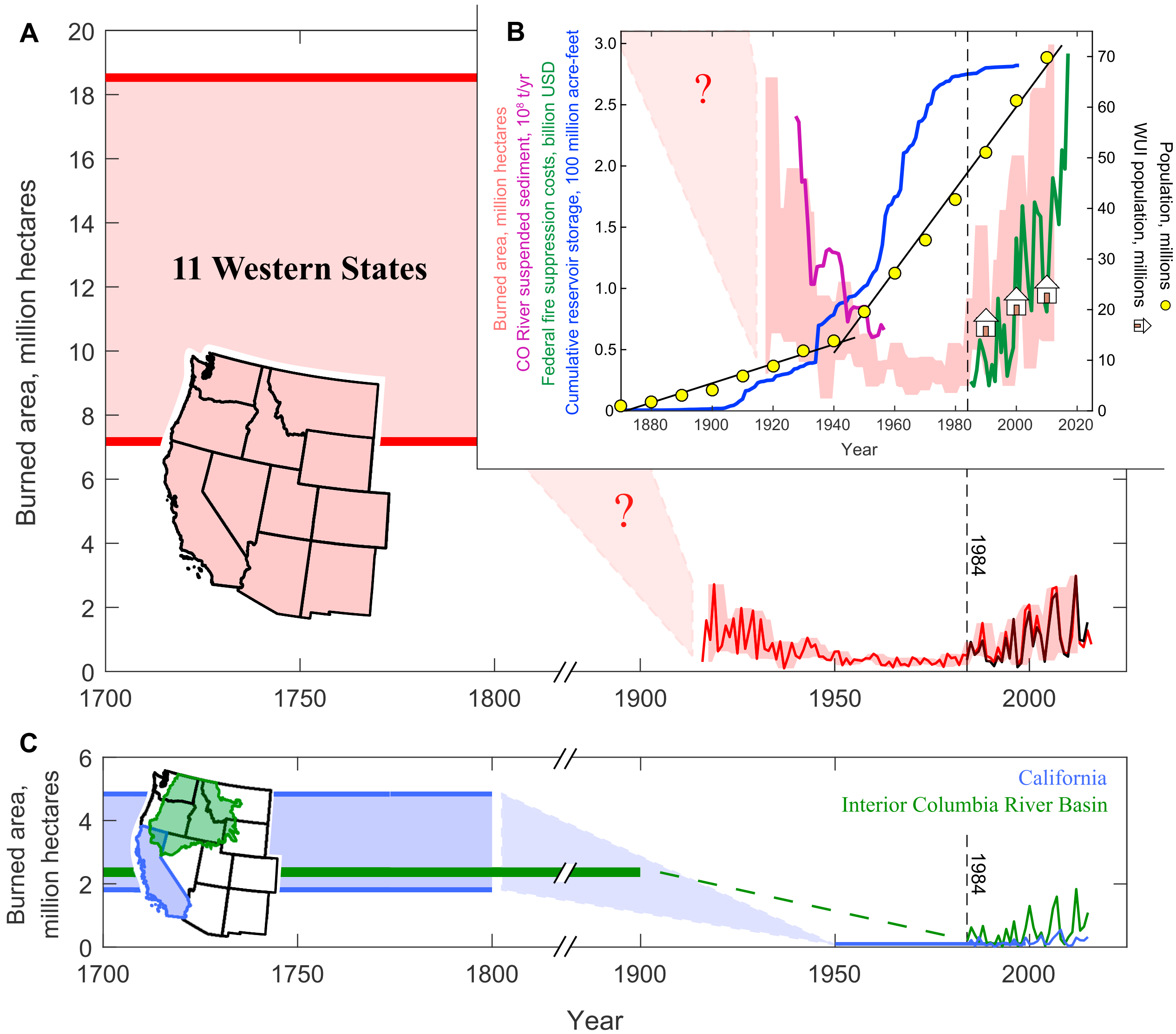

Figure 1. Burned area reconstructions and human dimensions of wildfire for the 11 western states. (a) Horizontal red lines show estimated maximum and minimum range for the *preindustrial* era (Leenhouts, 1998). The red line from 1916 to 2015 is based on adjusted Forest Service records of burned area, with shading for the 5-year 5th and 95th percentiles (1916–2003 data from Littell et al., 2009; updated 2004–2015 data provided by personal communication with J.S. Littell). The black line from 1985 to 2015 shows the remotely sensed record of fires >1,000 acres (Eidenshink et al., 2007). (b) The 5-year 5th and 95th percentiles of burned area (Littell et al., 2009; shaded red area) is overlaid by total population (yellow dots; Hobbs & Stoops, 2002; U.S. Census Bureau, 1975; U.S. Census Bureau, 2010), wildland urban interface (WUI) population (houses; Radeloff et al., 2017), federal fire suppression costs (green line; National Interagency Fire Center (NIFC), 2017), cumulative constructed water reservoir capacity (blue line; U.S. Army Corps of Engineers (USACE), 2006), and 5-year moving average of suspended sediment from the Colorado River at Lees Ferry from 1926 to 1960 (purple line; Graf et al., 2010; Oka, 1962). (c) Reconstructed burned areas for two subregions of the American West. California data (blue) includes the *prehistoric* range of area burned for median and high fire return intervals (Stephens et al., 2007), the average annual area burned from 1950 to 1999 (Stephens et al., 2007), and modern remotely sensed record of area burned in fires >1,000 acres (Eidenshink et al., 2007). Data for the Interior Columbia River Basin (green) includes the *historical* average annual burned area (Barrett et al., 1997) and modern remotely sensed record of area burned in fires >1,000 acres (Eidenshink et al., 2007). While these two regions comprise just 1/3 the area of the American West, the combined estimate of historical burned area from these studies is within the range estimated for the 11 western states (Leenhouts, 1998).

constructed reservoir storage (U.S. Army Corps of Engineers (USACE), 2006; Figure 1b). The near-complete extirpation of wildfire during this period skewed both perceptions and projections for the long-term sustainability of these water resources. Specifically, high-severity wildfires can cause significant erosion and deliver substantial amounts of sediment to rivers (Moody & Martin, 2001). Although long-term stream monitoring in this region is limited, the nineteenth and twentieth century declines in burned area presumably resulted in decreases in river sediment yields. One record, from the Colorado River at Lees

Ferry, demonstrates dramatic declines in sediment discharge from 1926 to 1960 (Oka, 1962; Figure 1b). This trend, along with declines in year-to-year variability, occurred throughout the upper Colorado River basin during the mid-twentieth century (Graf et al., 2010). While it is not possible to unequivocally determine the role that wildfire suppression played in these observed declines, the timing is coincident and the mechanisms linking the two are well understood (Figure 1b). Regardless, after decades of relatively modest sedimentation, western reservoirs are now vulnerable to increasing wildfire, especially high-severity events (Sankey et al., 2017).

While the area burning in the West is unexceptional with a longer-term perspective, it is possible that in some areas we are setting records with respect to fire severity and fire behavior, especially in ecosystems historically characterized by frequent, low-severity fire (Abatzoglou et al., 2017; Haffey et al., 2018; Picotte et al., 2016). The recent increases in burned area, potentially fire severity, and consequential post-fire erosion are of critical concern for water security, and post-fire sedimentation has already resulted in costly losses of water storage for major cities, such as Denver, CO (Bladon et al., 2014; Martin, 2016). Projections indicate that future increases in wildfire will cause sediment yields to at least double in 35% of western watersheds by 2050 (Sankey et al., 2017), thus, accelerating reductions, or potentially causing catastrophic losses, in water storage now relied upon by tens of millions of people. Replacing sedimented dams would be prohibitively expensive (Utah Division of Water Resources (UDWR), 2010), and given the recognition of the negative impacts of dams on river ecosystems, the construction of new dams is unlikely in the foreseeable future (Bunn & Arthington, 2002; Nilsson & Berggren, 2000; Poff et al., 1997). Therefore, other solutions are required.

A future without wildfire is not an option in the western United States. Fires have burned in this region for millennia, and now, the climate is warmer and drier, snowpack is lower, fire seasons are longer, and in some ecosystems, fuels have accumulated for over a century. The public must let go of an antiquated 1984 perspective of the West, when fire activity was at a minimum and water storage was at a maximum. The climate and landscapes have fundamentally changed since the mid-twentieth century, and the notion of near complete fire suppression is unrealistic. The current and future increases in wildfire activity are due to the combination of twentieth century land management policies and climate change. Understanding the historical magnitudes and accepting the future potential of wildfire in this landscape is pivotal if we hope to change human behaviors, ensure the implementation of realistic solutions, and find a way to coexist with fire.

First, we must accept that the responsibility of realigning public perspectives falls, at least in part, on the shoulders of the scientific community. Our publications, and associated press releases, must clearly articulate that western landscapes have a much higher potential to burn than we are experiencing today. Prior to western settlement, an estimated 4–12% of this landscape burned each year (Barrett et al., 1997; Leenhouts, 1998; Stephens et al., 2007). Continuing to publish high-profile science focused on recent and future trends of wildfire remains important, but these studies must place current fire metrics within the context of longer-term trends. Additionally, while a tremendous amount of research using tree ring fire scars, charcoal deposits, and other methods has provided insight into historical fire regimes across the West, more research is needed on historical fire attributes (e.g., size, severity, and patchiness), as well as on systems other than dry conifer forests. Developing a more complete understanding of wildfire history in the American West, and being mindful to place it within the context of ecosystem and human settlement trends, is a crucial step toward realigning public perceptions and facilitating the adoption of necessary strategies for land, fire, and water management.

Finally, we must recognize and accept that the diversity of western ecosystems necessitates that there can be no universal solution to managing fuels and fire and reducing risks to infrastructure (Moritz et al., 2014). In ecosystems adapted to low frequency, high-severity fires, we must avoid further development in the wildland urban interface, implement aggressive erosion mitigation after fires, carefully monitor the sedimentation of reservoirs, and, if required, consider preemptive reservoir dredging. In ecosystems adapted to high frequency, low-severity fire, thinning and prescribed burns are valuable approaches for reducing the risk of high-severity fire, particularly in areas where fuel loads are uncharacteristically high. Several projects, which aim to restore millions of acres of land and reduce the risk of catastrophic wildfire, have been initiated on Forest Service land across the country as part of the Collaborative Forest Landscape Restoration Program (Schultz et al., 2012). At local scales, a growing number of cities, including Flagstaff, AZ, and Santa Fe, NM, have implemented programs designed to mitigate the threat of high-severity fire and erosion in source watersheds critical to their communities (Bennett et al., 2014). These initiatives and practices are costly though, and despite the increasing allocation of resources and increasing number of treated acres, the solutions do not match the scale of the problem. Therefore, we must continue to increase *managed wildfire* acreage wherever possible. Allowing wildfire to burn under amenable conditions and where risks are low is our best strategy for reducing fuel loads and the risk of fires that are costly, dangerous to control, and burn with aberrant severity. More low-severity fire on the landscape will also reduce future risks of catastrophic post-wildfire erosion and importantly, sedimentation, which will extend the lifespan of reservoirs. As we adapt to more wildfire in the West, effective and proactive fuel and fire management will be crucial for our landscapes, infrastructure, safety, and long-term water security.

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