COMMENTARY

Human-caused climate change is now a key driver of forest fire activity in the western United States

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Effects of climate warming on natural and human systems are becoming increasingly visible across the globe. For example, the shattering of past yearly records for global high temperatures seems to be a near-annual event, with the five hottest years since 1880 all occurring since 2005 (1). Not coincidentally, the single hottest year on record, 2015, also broke records for area burned by wildfire in the United States (Fig. 1 *A* and *B*), eclipsing the previous high mark set just one decade prior (2). Scientists have known for some time that climate is a key driver of forest fires; records from the past and present (3–5) provide strong evidence that warmer temperatures are associated with spikes in fire activity. Therefore, recent increases in wildfire activity as the planet warms are not a surprise. However, just how much of the recent increases in forest fire activity can be attributed to human-caused climate change vs. natural variability in climate? This question has profound scientific, management, and policy implications, yet answers have thus far remained elusive. In PNAS, Abatzoglou and Williams (6) present strong evidence that human-caused climate change is increasing wildfire activity across wide swaths of forested land in the western United States. They demonstrate that human-caused climate change has lengthened the annual fire season (i.e., the window of time each year with weather that is conducive to forest fires) and, since 1984, has doubled the cumulative area in the western United States that would have otherwise burned due to natural climate forcing alone.

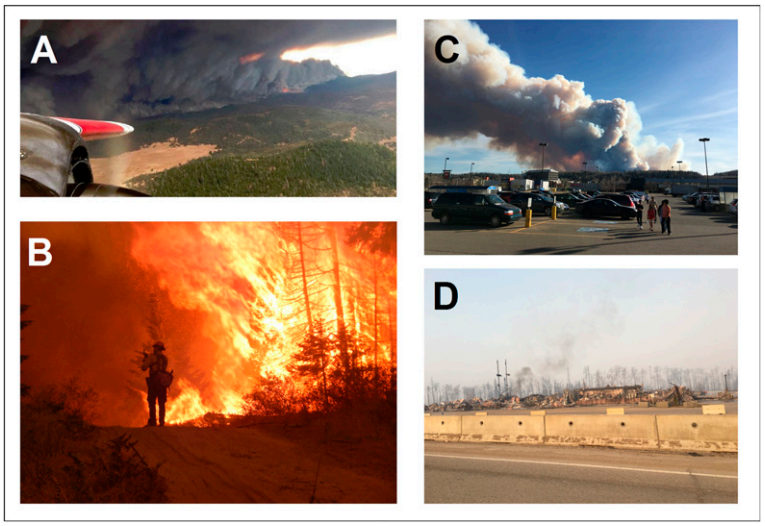

Fig. 1. Wildfire activity in western North America has been steadily increasing over recent decades, highlighted by the 2015 Valley Fire in northern California (*A*) and the 2015 Cougar Creek Fire in Washington (*B*), which both occurred during the hottest year on record globally. In May of 2016, the Horse River Fire burned through Ft. McMurray, AB, Canada, requiring regional evacuations as fire spread rapidly through intermixed forested and developed areas (*C*); eventually, more than 2,000 homes and other structures were destroyed (*D*). Human-caused climate change is now a key driver of forest fire activity, causing over half of the recent increases in fire weather and area burned by wildfire in the western United States (6). Photographs courtesy of CalFire (*A*), US Forest Service (*B*), and jasonwoodhead23 (*C* and *D*); acquired via https://creativecommons.org.

Abatzoglou and Williams (6) make an important leap forward in climate change science and global change ecology by linking approaches typically used in different lines of inquiry. Quantifying human-caused climate change has been a major focus of climatological and atmospheric research, where the sum of observed warming is parsed into components of natural and anthropogenic forcing (7). Fire scientists, on the other hand, have used a variety of approaches to understand climate-fire relationships by correlating past fire activity to past climate conditions over decadal (3, 5) to millennial (4) scales, documenting recent increases in fire-related weather (8), and/or modeling the likelihood of future fires given expected future climate trends (9, 10). These approaches nearly always infer the contribution of human-caused climate change to recent wildfire increases, whereas studies that quantify attribution have been exceedingly rare. In their study, Abatzoglou and Williams (6) combine rigorous statistical relationships between observed fire activity and multiple fire-related climate variables (e.g., vapor pressure deficit, potential evapotranspiration) with an ensemble of 27 state-of-the-art global climate models to ask how much of the observed fire weather and area burned in recent years can be attributed to human-caused climate change. They go beyond earlier studies (11) to quantify not only the presence but the magnitude of the anthropogenic climate-change effect on wildfire activity. This analysis

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is a critical step forward in assessing the effect that humans are having on our planet via fossil fuel emissions.

The study by Abatzoglou and Williams (6) is positioned within a broader dialogue about understanding the key drivers of natural disturbances in a rapidly changing world (12). Trends of increasing area burned in the western United States have been blamed on various factors, but rigorous attribution has yet to materialize. For example, outbreaks of native bark beetles (which are also triggered by warm/dry climate conditions) are routinely blamed for many recent forest fires, although scientific evidence has found weak to nonexistent links between beetle outbreaks and subsequent fire occurrence (13), area burned (14), and burn severity (15). A second common assertion is that past forest management (particularly on public lands) is to blame for recent increases in fire activity. Whereas evidence exists in some areas (particularly lower elevation and drier forest types) that past fire suppression has led to increased likelihood of severe fire (16, 17), higher elevation and moister forest types have been less affected by past fire suppression and forest management, and have historically burned in large, high-severity fires like the ones we see today (16, 17). Thus, across wide swaths of public lands, there is little evidence to suggest that recent upward trends in area burned are driven primarily by past forest management. Until recently, the "elephant in the room" has been the degree to which human-caused climate change is responsible for observed increases in forested area burned. The research by Abatzoglou and Williams (6) provides critical insight to fill this information void.

The relative importance of human-caused (vs. natural) climate change on wildfire activity is increasing over time (6), and combined with accelerating global fossil fuel emissions, suggests that a warm and fiery future will continue to affect forest ecosystems and challenge human systems. More and more forest fires that are followed by warm and dry conditions can lead to slower postfire forest recovery (18), which will inevitably lead to slower accumulation of postfire fuels (i.e., live vegetation, dead vegetation). Reduced fuels can drive negative feedbacks that may attenuate otherwise continued upward trends in climate-driven fire activity (9). However, the consequences of a warming climate, as well as associated increases in wildfire activity for forest resilience and ecosystem services, is an area of active research (19), with many questions still unanswered. In addition to ecological consequences for the findings of Abatzoglou and Williams (6), the implications of human-caused climate change on forest fires highlight the need for land-use policies in fire-prone areas that will minimize risk to human lives and built infrastructure (e.g., homes, businesses, utility corridors) (20). The 2016 evacuations, fires, and structure losses in Ft. McMurray, AB, Canada (Fig. 1 *C* and *D*), remind us that in a warm and fiery world, it is not if, but when, fire will threaten developed areas in and around forests.

The research presented by Abatzoglou and Williams (6) is an important leap forward in understanding how human-caused climate change is already affecting our planet in profound ways. Wildfires are important natural components of forest ecosystems throughout the western United States, where species are adapted to a particular range of fire frequency, size, and severity. However, rapid and unprecedented increases in fire activity under a warming climate may erode forest resilience over wide regions (16), threatening ecosystems, livelihoods, and communities. The science has been clear for some time that more forest fire is a symptom of a warmer climate; now, the science is clear that a substantial portion of accelerating forest fire activity today is caused by anthropogenic climate change. Unless we get serious about curbing human drivers of climate change, we should expect a fiery future in western US forest ecosystems and the communities that surround them.

Acknowledgments

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