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Up in smoke: California's greenhouse gas reductions could be wiped out by 2020 wildfires☆

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ABSTRACT

In this short communication, we estimate that California's wildfire carbon dioxide equivalent (CO_2e) emissions from 2020 are approximately two times higher than California's total greenhouse gas (GHG) emission reductions since 2003. Without considering future vegetation regrowth, CO_2e emissions from the 2020 wildfires could be the second most important source in the state above either industry or electrical power generation. Regrowth may partly of fully occur over a long period, but due to exigencies of the climate crisis most of the regrowth will not occur quickly enough to avert greater than 1.5 degrees of warming. Global monetized damages caused by CO_2e from in 2020 wildfire emissions amount to some $7.1 billion USD. Our analysis suggests that significant societal benefits could accrue from larger investments in improved forest management and stricter controls on new development in fire-prone areas at the wildland-urban interface.

1. Introduction

Recent evidence suggests that climate change contributes to increased wildfire activity in the western United States (Abatzoglou and Williams, 2016). California's summer wildfire burned area increased eightfold from 1972 to 2018 (Williams et al., 2019), and statewide climate change projections predict an amplification of wildfire risk due to higher temperatures and drier conditions (Westerling, 2018). Climate change exacerbates fire risks already stoked by increasing development near the wildland-urban interface (WUI) that have made humans the main ignition source in California (Keeley and Syphard, 2018), as well as decades of fire suppression and underinvestment in preventive measures such as mechanical clearing or prescribed burns (Keeley and Syphard, 2021; Kolden, 2019; Radeloff et al., 2018). Wildfires, in turn, release GHG emissions that can contribute to climate change.

California experienced its most disastrous wildfire year on record in 2020. CalFire, the state agency responsible for leading California's wildfire prevention and suppression, reports that 1.7 million hectares burned in 2020 (CalFire, 2022). Many of the worst fire years in California's history have occurred in the past 20 years, with eighteen of the top 20 most destructive fires in terms of loss of life and property since 2000 and five in 2020 alone (CalFire, 2021). The 2020 fires have been followed by another extreme fire season with 1.0 million hectares burned in 2021.

In addition to the immediate loss of life and property, hospital admissions and premature deaths have likely happened because of the smoke exposure (Cascio, 2018; Fann et al., 2018; Reid et al., 2016; Wang et al., 2020), which blanketed large parts of the state with tens of millions of people with unhealthy air quality that persisted for months in some locations. Recent estimates put the economic costs of direct health costs at $32 billion for 2018 (Wang et al., 2020). Future climate projections suggest that wildfires will become an increasingly important source of air pollution in the western U.S. (Ford et al., 2018; Liu et al., 2016).

When forests burn and are not balanced by vegetation regrowth, they shift from a natural sink to a source of carbon (van der Werf et al., 2017). This can represent a positive climate feedback loop in which increased GHG emissions contribute to climate change and further increase wildfire risk. Although wildfires are a natural feature of many ecosystems in California, the increase in severe and frequent wildfire events has raised the possibility of transformed post-fire ecosystems as new plant communities regrow following fire events that alter carbon

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sequestration potential (Bowman et al., 2020). Regrowth relies on several factors including species burned, drought, and active replanting (Kibler, 2019). Even if long-term regrowth occurs, however, the carbon emissions occurring in the next 15–20 years will make it difficult to reach emission reduction targets needed to avert the 1.5 degree C increases in mean global temperature advocated by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2018). Recent studies on the Australian wildfires have suggested that the magnitude of the fires in combination with the broadleaf species being burned likely places fires somewhere in between carbon neutrality and complete emissions (van der Velde et al., 2021).

In this short communication, we quantify the likely carbon emissions that occurred in 2020 from wildfire activity in California. We then situate these emissions in the context of other leading GHG emissions sectors in California. We conclude with policy recommendations for reporting of routine wildfire emissions and for increased investment in preventive measures.

1.1. Data and methods

Given substantial uncertainties among fire emissions inventories (Liu et al., 2020), we obtained multiple sources of fire emissions data for 2003–2020. First, we accessed satellite-based fire CO_2 emissions from the Global Fire Emissions Database version 4 with small fires (GFED4s) (1997-present; considered preliminary since 2017) and Global Fire Assimilation System version 1.2 (GFAS) using FIRECAM (Liu et al., 2020). These inventories represent "bottom-up" and "top-down" approaches to fire emissions estimation, respectively, and have shown the best correspondence with aerosol observations in North America (Carter et al., 2020). Although GFED and GFAS do not distinguish between wildfires and other landscape fires such as agricultural or prescribed burns, we expect this contribution to be minor in California. We also obtained wildfire-specific emissions estimates from the California Air Resources Board (CARB) (2000–2020), which combines individual fire perimeters with a wildland fire emissions model (CARB, 2020). The average across inventories is 127 mmt CO_2e for 2020 (ranging from 101 to 171 mmt CO_2e) and 18 mmt CO_2e for 2003–2019 (ranging from 15 to 22 mmt CO_2e).

We next compared wildfire emissions to sectoral GHG emissions for 2003–2020 to maintain consistency with availability for all three wildfire emissions inventories (CARB, 2021). In 2019, the CARB reported 418 mmt CO_2e emissions for all sources with the top 3 being transportation (166 mmt CO_2e), electrical power generation (59 mmt CO_2e), and industry (88 mmt CO_2e). For 2020, we assume constant emissions from the year 2019, as this was the last year where the CARB estimated sector-specific contributions to CO_2e, although this may be an underestimate due to potential emissions reductions during the COVID-19 pandemic (Liu et al., 2021).

Finally, to assess the socioeconomics benefits of reducing these CO_2 emissions, without considering the co-benefits of air pollution reductions, we apply the social cost of carbon (SC–CO_2). The SC-CO_2 is an estimate of the marginal damage caused by the emissions of an extra ton of CO_2 today in net present value. This value, adopted by the Biden administration in February 2021, is $51 per ton with a 3% discount rate in 2020 USD (Interagency Working Group, 2016). We also apply a value of the SC-CO_2 where damages are restricted only to the United States. While this lower value of $7.1 per ton in 2020 (Governmental Accountability Office, 2020) does not capture the global nature of emissions, it does allow us to attribute the local component of global damages caused by the fires.

2. Results

We first compared sectoral emissions to wildfire emissions, which indicate an approximate release of 127 mmtCO_2e in 2020, nearly seven times the 2003–2019 mean. From 2003 to 2019, California's GHG emissions declined by 65 mmt CO_2e (−13%), largely driven by reductions from the electric power generation sector. The 2020 fire season alone is two times higher than California's total GHG emissions reductions and would comprise 49 percent of California's 2030 total greenhouse emissions target of 260 mmtCO_2e (Fig. 1) (CARB, 2017).

Global monetized damages caused only by CO_2 from California's fire emissions in 2020 is approximately $7.09 billion in net present value when applying SC-CO_2 from the Biden Administration with a constant 3% discount rate. This value is reduced to approximately $986.9 million in damage for the U.S. when considering only domestic damages. If we consider what this implies for California only, we calculate the median damages to California as a percent of U.S. damages in 2080–2099 implied by Hsiang et al. (2017). This gives values of 8.5%, 12.1%, 9.4% for Representative Concentration Pathways (RCPs) 2.6, 4.5, and 8.5 respectively. Scaling the previous U.S.-only value to the average of these percentages, this would imply that the carbon emissions-only damages for California would be approximately $98.7 million in net present value.

3. Conclusions

In this short communication, we analyzed the likely CO_2e emissions from wildfires in California during 2020. Averaging three fire emissions estimates, we find that approximately 127 mmt CO_2e were emitted in 2020. We emphasize that our wildfire emissions estimates do not consider subsequent vegetation regrowth following fires so this is considered an upper bound for net wildfire GHG contributions to the atmosphere. This regrowth, however, could take decades or longer depending on the type of ecosystem that burned.

If we compare fire GHG emissions to total GHG emissions of 418 mmt CO_2e total in 2019, this amounts to a 30% increase in total emissions by all sectors. This makes the GHG emissions from wildfires the second most important source in the state, after transportation (166 mmtCO_2e), but above either industry or electrical power generation (88 and 59 mmt CO_2e, respectively). Viewed from the perspective of what this means for wildfire emission reductions from all other sectors combined, if we compare to reductions from 2003 to 2019 from 483 to 418 mmt CO_2e, the likely amount of increase from the fires is close to double all the emission reductions achieved in the state from 2003 to 2019.

The economic damages are informative for two key reasons. First, they represent a currently unquantified aspect of damages due to fires that are incurred globally, in the U.S., and in California itself. These damages should be counted in addition to fire control costs, damages from air pollution, and direct loss of life and property. Second, they provide a benchmark against which to compare the costs of prevention measures, based purely on climate change mitigation, and not including co-benefits of reduced pollution, lower property risk and loss, and other damages associated with fire risk. The Federal government and California recently signed a memorandum of understanding to increase to 1 million acres per year forest treatment to prevent wildfires in the State (State of California, 2020); in 2021, California invested $1.5 billion in wildfire resilience programs, including prescribed burning (California Wildfire & Forest Resilience Task Force, 2022). If future treatments are moderately effective and reduce wildfire risk and subsequent CO_2e emissions by 20%, this would reduce 20% of the total $7.09 billion in externality costs that we have calculated (i.e., $1.42 billion in benefits). Including the carbon mitigation benefits further justifies the wildfire prevention costs.

Our analysis suggests several notable bit findings. First, wildfires in California have become a major and growing source of GHG emissions. Over the long to very long term, regrowth could alleviate some of the emissions, but this is unlikely to occur on the time scale necessary to meet near and medium-term emission targets needed to avert passing the 1.5 degree C threshold. Second, the magnitude of the emissions makes wildfires the second most important source of emissions in 2020 behind transportation emissions, and one that appears likely to grow

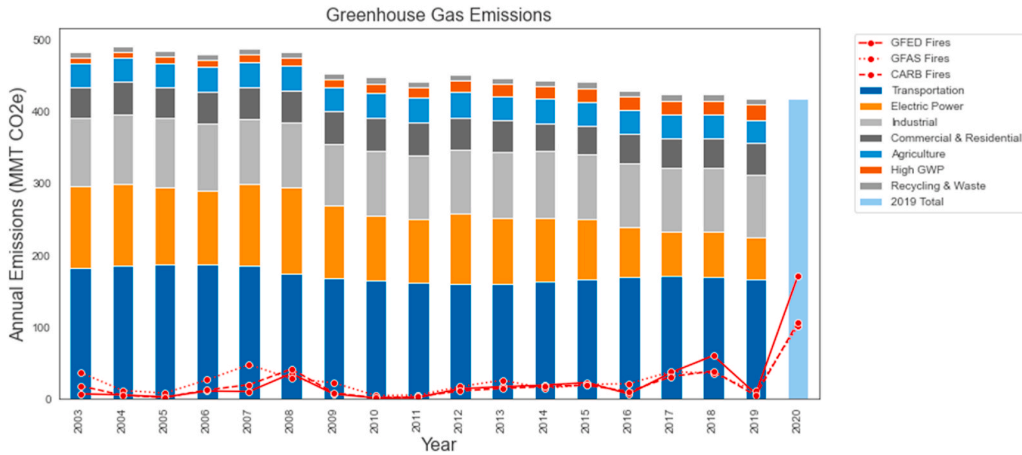

Fig. 1. Annual emissions from individual sectors and wildfire emissions. CARB, GFAS1.2, and GFED4s wildfire emissions shown as red lines (not considering vegetation regrowth). **Note:** Since data is not yet available, 2020 non-fire emissions are assumed to be equal to CARB 2019 estimates. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

with future climate change. Average wildfire emissions from the past five years (~46 mmt CO_2e from 2016 to 2020) ranks above the most recent individual contributions from the Commercial & Residential, Agriculture, Recycling & Waste, and High Global Warming Potential sectors. The latter includes fluorine-containing gases that destroy stratospheric ozone; sources include electricity transmission and distribution and semiconductor manufacturing. Third, wildfire emissions in 2020 essentially negate 18 years of reductions in GHG emissions from other sectors by a factor of two. Fourth, the additional global damages due only to the contribution of these emissions to climate change can be valued at $7.09 billion.

The findings imply several research directions and policy actions. The externalities caused by fire emissions incurs damages globally and in California, and the economic value should be considered alongside other direct costs of fires (Feo et al., 2020), including prevention and suppression. Wildfire emissions are not routinely reported with other key emission sources such as transportation, industry, and power generation. While wildfire emissions tend to be more variable than other sectors, it is still important to track these emissions to ensure near and medium-term emission reduction targets are met. A likely consequence is that wildfire emissions have not received nearly the same level of societal investment or attention as emissions from other sectors. Although wildfires are to some extent natural occurrences, human activity contributes to making wildfires "unnatural disasters" through anthropogenic climate change and development at the WUI in fire prone areas. Moreover, forest management policies focused on fire suppression rather than on preventive measures such as mechanical clearing and prescribed burning activities also likely increases the risk of large, destructive wildfires. If fires are no longer in balance with ecosystem regrowth, we risk different vegetation communities regrowing with less potential for carbon sequestration. A need also exists to develop accessible quantitative tools for policymakers and the public to understand how wildfire risk can be reduced through better management, how much loss of life and property can be avoided, and how much it will cost to achieve these goals. This will allow for more accurate assessment of investments in improved forest management or prevention of development in fire prone areas at the wildland-urban interface.

Author statement

M. Jerrett: Conceptualization, Methodology, Writing – original draft, Reviewing & Editing. A. Jina: Methodology, Writing-Reviewing & Editing. M. Marlier: Conceptualization, Methodology, Writing – original draft, Reviewing & Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Funding for Dr. Jerrett was supplied by the UCLA Center for Healthy Climate Solutions.

Data availability

Data will be made available on request.

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