Climate Change and Fire Suppression: Drivers of Fire Regimes at Actionable Scales

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Key Findings

The relative influence of climate change and fire exclusion vary with soil moisture (Figure 1), which itself is influenced by climate and local topography:

- Climate change increased burn probability and led to larger, more frequent fires in locations where soil aridity was relatively low (i.e., time-averaged soil moisture >35%).
- In the most arid locations (i.e., time-averaged soil moisture <25%), climate change promoted drought stress and reduced fine fuel loads, which in turn reduced burn probability.
- In locations with intermediate soil aridity (25-35%), the effects of climate change and fire suppression varied in response to local trade-offs between aridity (which makes fuels more flammable) and productivity (which increases fuel loads).

Even within watersheds, at fine scales, risk management must be spatially and temporally explicit to optimize effects.

Keywords. Fire suppression;anthropogenic climate change; wildfire: risk; wildfire: fuel; soil moisture; fuel management; wildfire: frequency

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The frequency of catastrophic wildfires is increasing around the globe. Our ability to mitigate the risks associated with these fires, and the toll they take on communities, life, and the environment, will depend in large part on understanding their driving causes. But there remains significant debate over how interacting factors like climate change and fire suppression enable ignitions to grow into extreme wildfires. While regional syntheses attribute increases in wildfire activity to both rising global temperatures and fuel accumulation due to historical fire suppression, they have yet to separate the influence of these drivers at watershed or even finer scales. Understanding how these factors interact is crucial for determining when and where fuel reduction treatments will be most effective.

Researchers at Washington State University analysed how historical climate change and fire suppression are influencing wildfire activity at management-relevant scales, focusing on two mixed-conifer watersheds in Central Idaho: Johnson Creek, a 565-km^2 sub-catchment of the South Fork Salmon River, and Trail Creek, a 167-km^2 sub-catchment of the Big Wood River. Using a novel modelling technique, researchers simulated the frequency, magnitude, and risk of wildfires over a four-decade period (1980-2017) with and without historical climate change and fire suppression. They developed scenarios informed by historical climate data, including temperature and precipitation, current understanding of climate change trends, and fire suppression, modelled as complete fire exclusion. The modelling framework enabled them to examine how the drivers of wildfire are modified by local environmental conditions, including gradients in aridity and vegetation productivity.

The Varying Influence of Climate Change and Fire Suppression on Watersheds

Johnson Creek. In the Johnson Creek watershed, soil moisture was relatively high, which can limit fire spread by reducing fuel flammability. However, climate change increased temperatures which, in turn, increased fuel aridity and the size and number of wildfires.

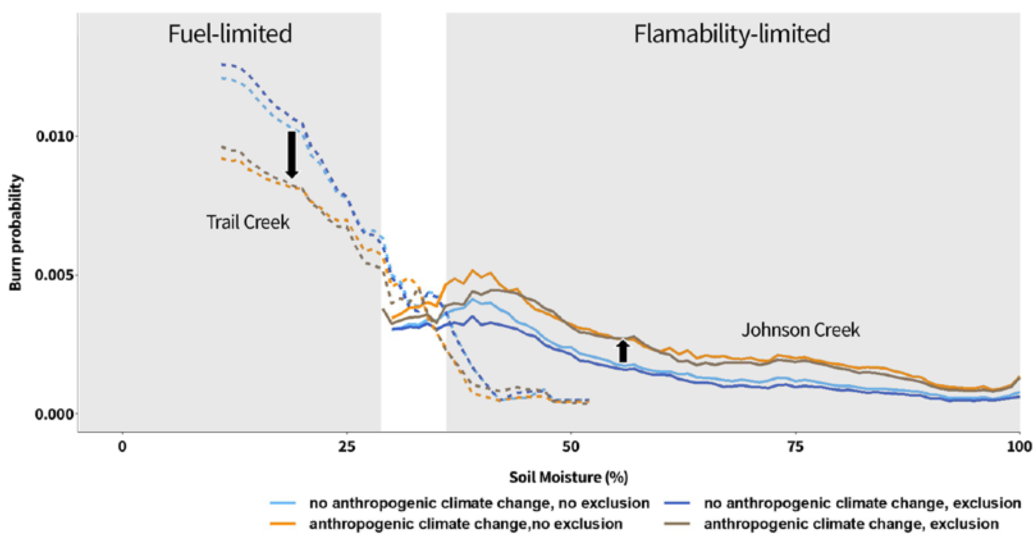

Figure 1. *Burn probability along a soil aridity gradient for Trail Creek (dashed lines) and Johnson Creek (solid lines), with and without climate change (orange vs. blue lines), and with and without fire exclusion (dark blue and orange vs. light blue and orange lines). Climate change increased burn probability by drying fuels in the most mesic locations (i.e., locations where temporally averaged soil moisture was high; see difference between blue and orange lines, highlighted by the upward pointing arrow). In the most arid locations, climate change promoted drought stress and reduced fine fuel loads, which in turn reduced burn probability (see difference between blue and orange lines, highlighted by the downward pointing arrow).*

This led to larger, more frequent fires, compared with scenarios that excluded climate change, leading to a 40% increase in burned area compared to simulations without climate change. Meanwhile, fire exclusion increased fuel loading, but still decreased wildfire size and frequency, leading to a 15% decrease in burned area compared to simulations that did not include fire exclusion. This occurred because historical suppression increased shading provided by denser overstory canopies may also have contributed to the decrease. Field observations have shown that solar radiation and wind are less able to penetrate closed canopies, leading to lower sub-canopy temperatures and greater humidity, which can reduce surface fuel accumulation and promote greater moisture retention. Overall, Johnson Creek was found to be a climate- or flammability-limited system.

Trail Creek. In the Trail Creek watershed, wildfire regimes responded differently. Under climate change scenarios, net primary production slowed and decomposition increased which, in turn, decreased fuel loads. In contrast to Johnson Creek, fire frequency was not impacted, though including climate change in the scenario *decreased* burned area by 19%, due to a reduction in the occurrence of large fires. Meanwhile, fire suppression only increased burned area by 2% over the analysis period because the watershed was arid enough that fire exclusion did not increase net primary production or fuel accumulation in most locations.

Management Implications

Results suggest that the risk of large and severe wildfires in more arid watersheds may increase along with rising global temperatures, even with management practices to reduce fuels. Also, even though climate change was found to be the strongest driver of wildfire size, frequency, severity, and risk in Johnson Creek, the

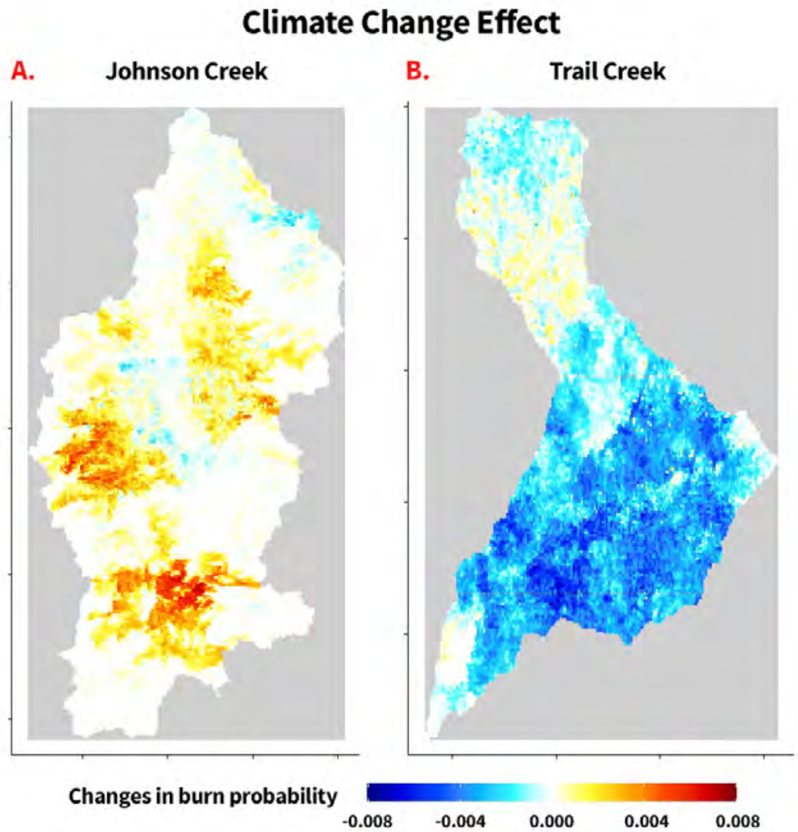

Figure 2. *Changes in expected burn probability and how they varied across Johnson Creek (panel A) and Trail Creek (panel B). Yellow and orange areas show the specific locations where burn probability has likely increased due to climate change, and blue areas show those locations where burn probability has likely decreased due to climate change. Johnson Creek, with generally higher soil moisture, mainly shows expected increases, though large portions of the watershed may have seen little to no change, and even slight decreases in burn probabilities. Trail Creek, on the other hand, likely had mostly decreases in burn probability, though also has areas that have seen increases.*

strength of the climate-fire relationship varies according to position within the watershed and site aridity. Therefore, adaptive management is critical as local aridity may increase under climate change conditions.

While climate change is a major factor increasing the frequency of large wildfires across the globe, there are still many regions where past suppression still plays a dominant role. Reducing forest density is an approach that is often used in fuel-limited forests where decades of suppression have significantly increased fuel loads. However, density reductions can sometimes have unintended consequences, particularly when vegetation growth is enhanced by the treatments, leading to greater evapotranspiration and drier conditions, which in turn increases fuel aridity and subsequent fire risk.

Because fuel management often occurs at fine scales, spatially explicit models are needed to project how different areas within a watershed will respond to fire exclusion or fuel treatments under the shifting conditions brought about by climate change. It is therefore important to consider both spatial heterogeneity and climate change trends (e.g. Figure 2) in management planning and policy, particularly in light of the dominant role that climate change is playing in managed landscapes across the world.

Foundational Publications

Hanan, E.J., Ren, J., Tague, C.L., Kolden, C., Bart, R., Kennedy, M., Abatzoglou, J. & Adam, J. 2021. *How climate change and fire exclusion drive wildfire regimes at actionable scales.* Environmental Research Letters, 16, 024051. https://doi.org/10.1088/1748-9326/abd78e