Wildfire Impacts on Human Health and Mobility

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Extended Abstract Submission

Introduction

Wildfires have become an increasingly salient hazard in recent years. Wildfire areal extent–the amount of acreage burned per year–has gone up for nearly every state in the 21st century (*US EPA*). Wildfire frequency, intensity (energy released) and severity (losses accrued) have all increased (Westerling et al., 2006) due to misguided wildfire management practices, drought, record temperatures, insect blight, and individuals settling and firms siting in the Wildland-Urban Interface. Preparation and management is particularly challenging for wildfires compared to other natural hazards because of the complexities of fire ecology as well as large uncertainty surrounding occurrence, duration, and spread for any event. Beyond these existing root causes, dynamic pressures, and unsafe conditions leading to wildfire disasters, climate change projections indicate increased wildfire hazard over the next century (Pechony and Shindell, 2010). California alone witnessed the two largest fires in state history, the Carr and Thomas Fires, as well as the most destructive, the Tubbs Fire, within the past year. Direct losses from wildfires are well studied and easily measured; these include property damage and mortality. Indirect losses from wildfires also exist, such as disruption of ecosystem services, population displacement, and population health effects. There are relatively fewer studies on this latter set of losses due to less straightforward measurement protocols, among other reasons. As a result, the full impact of wildfire disasters goes unseen, especially for the most vulnerable in our society.

Our study aims to measure indirect losses from wildfire hazards. Although this work exists in a national context in which wildfires and related hazards capture greater amounts of our attention and resources, we limit our geographic scope to California. The most populous state in the United States is, not surprisingly, also the most wildfire prone, i.e., the largest number of households at risk from experiencing high or extreme risk wildfires (*Insurance Information Institute*). We break our inquiry into three related research questions: 1) how do wildfire disasters influence population settlement patterns and processes; 2) what are the population health impacts from wildfires; and 3) will climate change increase wildfire losses related to population health and displacement? Our overarching hypothesis is that wildfire disaster-related losses extend beyond property damage and mortality, they do so in a meaningful way, and these indirect losses will increase over time in both scope and magnitude. Meaningful for the purposes of this research can be represented as an issue of equity, whereupon a loss qualifies as such if its distribution disproportionately impacts underprivileged and disenfranchised population groups. Beyond answering these basic questions, we plan to contribute to loss estimation methods by cross-validating between comparable datasets. Wildfires are among the costliest natural hazards in the United States. Elevated wildfire risk moving forward therefore demands greater attention towards understanding the concurrent, less immediately observable losses.

Literature Review

The relevant literature can be broken down into a few categories: modeling risk of natural disasters, analyzing consequences, and evaluating vulnerability. California has long been recognized as an epicenter for natural disaster risk, including fire risks, particularly those related to population growth in areas of Wildland-Urban Interface (WUI) (Radeloff et al., 2018; Hammer et al., 2007). While neither the largest nor most deadly, the 1991 fire in the Oakland-Berkeley hills was a foreshadowing of an increasingly common fire pattern: a minor fire escalates, spurred on by arid conditions and wind (FEMA 1991). Simulations consistently show that this pattern is likely to grow as a result of climate change, population growth, and land use change (Westerling and Bryant, 2008; Kloster et al., 2012; Bryant and Westerling 2014).

The effect of population on wildfire hazards will be significant, but what about the consequences of fires for population? Little is known about demographic responses to fire. Research in disaster demography has examined contexts as diverse as Indian Ocean tsunami (Gutmann and Field, 2010); Hurricanes Andrew (Smith and McCarty 1996) and Katrina; pandemics (e.g. the worldwide 1918 influenza outbreak); man-made disasters (such as the September 11, 2001 attacks); and 'slow-motion' disasters such as sea level rise in Louisiana (Hauer et al., 2018). Displacement due to disaster is associated with negative mental health impacts, but these tend to attenuate over time. There are few consistent findings across this literature and it is exceedingly difficult to generalize due to the selection processes operating in different contexts. Whatever effects can be estimated are the product of both the impact of the disaster and behavioral responses in anticipation and response to the event (Frankenberg et al. 2014); these limitations apply even to natural experiments (Johnson-Hanks, forthcoming).

In the present paper, we focus on understanding better the characteristics of populations impacted by increasing fire hazards. Fire hazards consist of destruction and displacement, but also impacts on air quality (measured by concentration of PM2.5, Microparticles associated with negative health outcomes). Previous research has found that urban PM2.5 is higher than rural areas, so we wish to examine whether lower air quality from fires has reduced the gap in air quality. In the past, WUI fires affected more affluent homeowners; however, when we examine indirect health impacts from air quality and changes in susceptibility resulting from demographic and climate change, the new geography of vulnerability may look quite different.

Loss assessment occurs following nearly every wildfire event. These assessments typically comprise area burnt, structures damaged and destroyed, and injuries and deaths. These losses represent an estimation of the profound impact wildfires make to ecosystems, people, and the economy. However, these loss assessments do not capture the full breadth and depth of wildfire impacts on these systems. Studies looking at indirect losses from wildfires tend to focus on health, with few addressing issues posed by population displacement. A systematic review of health impacts from wildfire smoke found consistent associations with respiratory disease and tentative evidence for cardiovascular disease and mortality (Liu et al., 2015). An older review found a thin body of research from two main study categories: economic costs of wildfire-related health impacts and health risk from wildfire smoke–the authors identified a need for better understanding of wildfire-related health impacts (Kochi et al., 2010). Specific studies that address health impacts of wildfires show increased rates of asthma (Bowman and Johnston, 2005).

Data

We utilize several datasets for this research:

- Wildfire extent: 1) Moderate Resolution Imaging Spectroradiometer (MODIS) Fire Detection data, a remotely sensed United States Department of Agriculture geospatial dataset.
- American Community Survey (ACS) 5-year data providing demographic profiles, socioeconomic status, and housing quality.
- Population mobility: 1) historic housing units in decadal increments in spatio-temporally contiguous Census Block Groups(Hauer et al., 2018), and 2) a set of county-level population projections for the US ("Population projections for all U.S. counties by age, sex, and race controlled to the Shared Socioeconomic Pathways.").
- Population health: California?s Office of Statewide Health Planning and Development (OSHPD) data on primary care, specialty, and emergency room visits for patient diagnostic histories.
- Social equity: 1) Pacific Institutes Social Vulnerability Index
- Air quality – $PM_{2.5}$: 1) United States Environmental Protection Agency (EPA) gridded hourly air quality monitoring station data, and 2) MODIS aerosol optical depth (AOD) remotely sensed data.

Methods

Our first step integrates the various datasets to comparable spatial and temporal scales. This will vary based on the specific analytical problem we address. For example, if we are interested in how $PM_{2.5}$ from wildfire smoke impacts hospital visits for respiratory illness, we scale both $PM_{2.5}$ datasets to correspond to a service area buffer for any given hospital. Additionally, we would scale down the EPA $PM_{2.5}$ hourly dataset to an annual resolution to agree with the OSHPD data.

The next step, which is somewhat concurrently completed with the previous, determines the relevant spatial unit of analysis. There are two main aims depending on the dataset. For population mobility, the relevant spatial unit for an *affected* area comprises administrative units that experienced wildfire-related property damage. For population health, buffers will typically be either bands or polygons demonstrating a distribution of distance or absolute proximity to wildfires, respectively.

Following these data integration and concordance tasks, we move on to modeling. The first modeling task assesses how administrative units experience population change following a wildfire disaster. Population would appear to decline following a wildfire due to loss of housing stock, however many people may choose to stay in the functional region because of constraints such as work, school, and social networks. We would then evaluate whether the migratory potential of wildfire disasters is greater and less equitable in places that are more vulnerable by using the Social Vulnerability Index.

The second modeling task tests whether there is a statistically significant association between wildfires and health impacts, including respiratory, reproductive, and mental health. Wildfire exposure includes both air quality and geographic proximity. These analyses would also evaluate the role of vulnerability in the distribution of impacts.

Lastly, we utilize climate change projections, specifically regarding shifts in wildfire hazards, to explore how these relationships might change over time and space. We pay particular attention, as in the previous analyses, to the distributional impacts of wildfires.

References

Bowman, David M.J.S. and Fay H. Johnston (2005). "Wildfire Smoke, Fire Management, and Human Health". In: *EcoHealth* 2.1, pp. 76–80.

Gutmann, Myron P. and Vincenzo Field (2010). "Katrina in historical context: environment and migration in the U.S." In: *Population and Environment* 31.1, pp. 3–19.

Hammer, Roger B. et al. (2007). "Wildlandurban interface housing growth during the 1990s in California, Oregon, and Washington". In: *International Journal of Wildland Fire* 16.3, pp. 255–265.

Hauer, M. "Population projections for all U.S. counties by age, sex, and race controlled to the Shared Socioeconomic Pathways."

Hauer, M. et al. (2018). "No Landward Retreat: Examining 80 years of population migration and shoreline change in Louisiana."

Insurance Information Institute. `https://www.iii.org/`. (Accessed on 09/17/2018).

Kloster, S. et al. (2012). "The impacts of climate, land use, and demography on fires during the 21st century simulated by CLM-CN". In: *Biogeosciences* 9.1, pp. 509–525.

Kochi, Ikuho et al. (2010). "The economic cost of adverse health effects from wildfire-smoke exposure: a review". In: *International Journal of Wildland Fire* 19.7, pp. 803–817.

Liu, Jia C. et al. (2015). "A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke". In: *Environmental Research* 136, pp. 120 –132.

Pechony, O. and D. T. Shindell (2010). "Driving forces of global wildfires over the past millennium and the forthcoming century". In: *Proceedings of the National Academy of Sciences* 107.45, pp. 19167–19170. eprint: `http://www.pnas.org/content/107/45/19167.full.pdf`.

Radeloff, Volker C. et al. (2018). "Rapid growth of the US wildland-urban interface raises wildfire risk". In: *Proceedings of the National Academy of Sciences*. eprint: `http://www.pnas.org/content/early/2018/03/06/1718850115.full.pdf`.

US EPA. `https://www.epa.gov/environmental-topics`. (Accessed on 09/17/2018).

Westerling, A. L. and B. P. Bryant (2008). "Climate change and wildfire in California". In: *Climatic Change* 87.1, pp. 231–249.

Westerling, A. L. et al. (2006). "Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity". In: *Science* 313.5789, pp. 940–943. eprint: `http://science.sciencemag.org/content/313/5789/940.full.pdf`.