

County level understanding of the health impacts of increasing wildfire smoke

Yuanyu Xie, Denise L. Mauzerall Princeton University



Motivations

- There has been a marked **increase in North America wildfires** and **smoke pollution** in recent decades
- Previous health impact assessments of increasing wildfire smoke **have large uncertainties** as they
 - Mostly rely on the **hazard ratio** from all source $PM_{2.5}$ instead of wildfire specific $PM_{2.5}$
 - Have not fully considered **spatially and temporally varying socio-demographic factors** (population, aging, baseline mortality rate)
- We aim to improve the estimations of mortality attributable to smoke $PM_{2.5}$ at the county level

Methodology

$$Mortalities_{i,a,t} = Population_{i,a,t} \times Y_{0,i,a,t} \times (1 - \frac{1}{HR_{i,a,t}}) \quad i - \text{county}; a - \text{age}, t - \text{year}$$

Demographic datasets

- Population density
- Age distribution
- Race/Gender

Source: census.gov

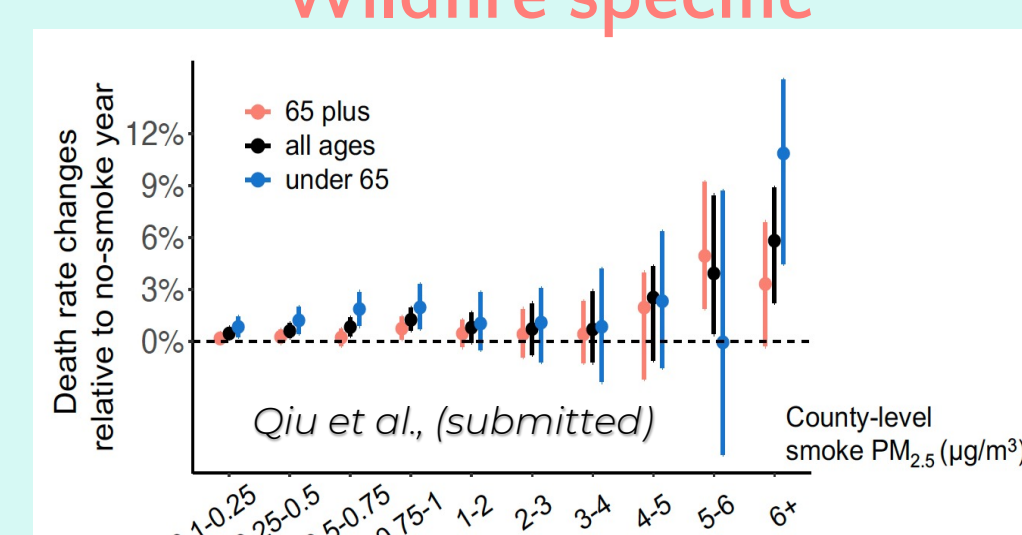
Baseline mortality rate

- Non communicable disease
- Lower respiratory infection
- All

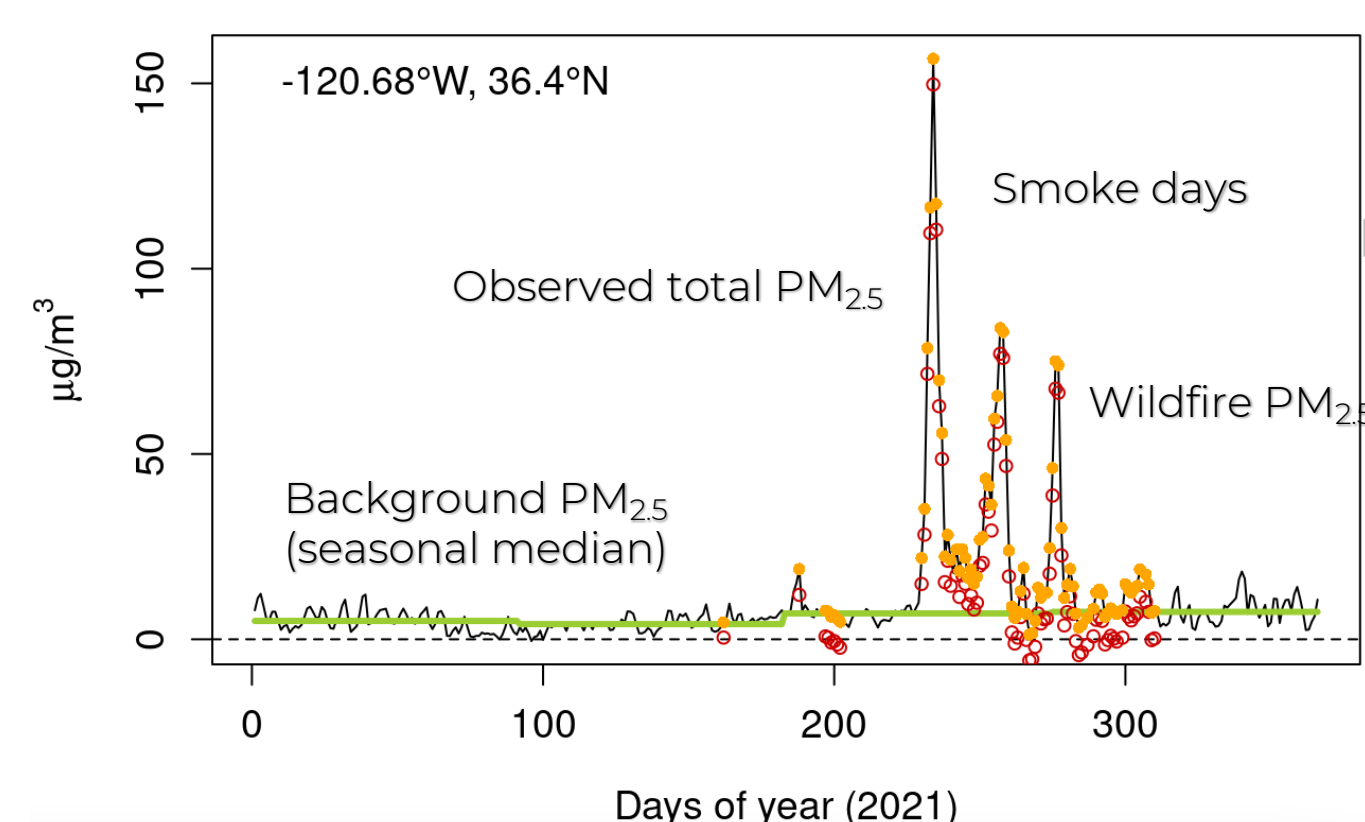
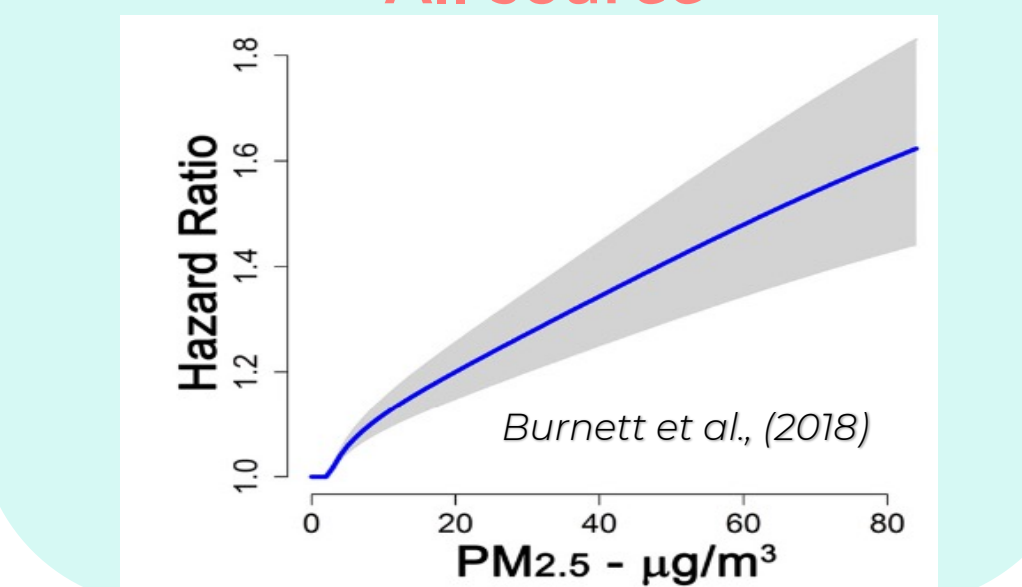
Source: Dwyer-Lindgren et al., (2023)

Hazard Ratio

Wildfire specific



All source



Changing wildfire $PM_{2.5}$ and socio-demographic factors since 2006

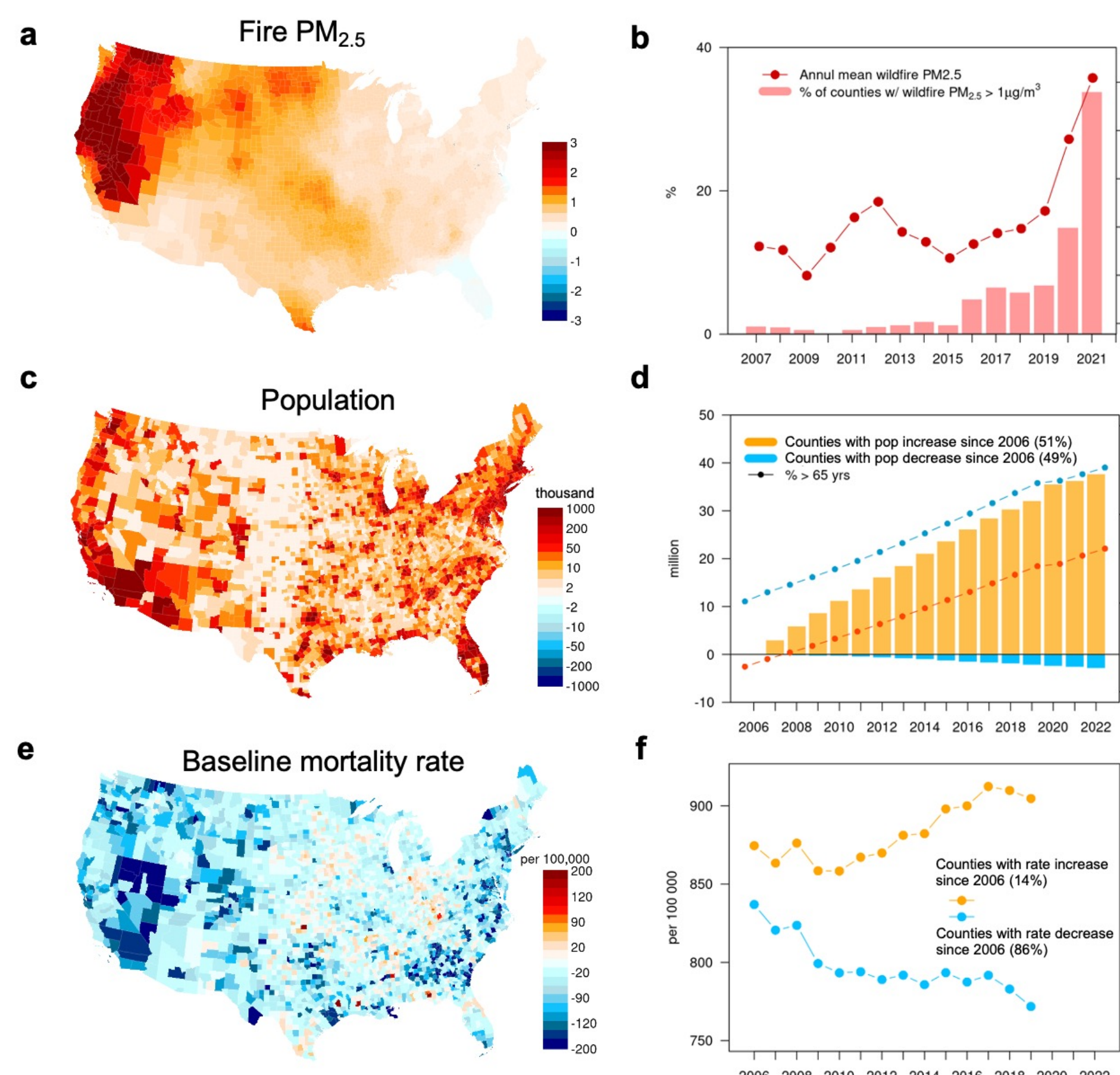


Figure 1. Changes in wildfire $PM_{2.5}$ and demographic factors during 2006-2022. (a,c,e) county-level changes between 2020-2022 and 2006-2008; (b,d,f) time series over the US during 2006-2022.

Wildfire $PM_{2.5}$

- Annual mean $PM_{2.5}$ from wildfires **tripled** in 2020-2022 relative to 2006-2008.
- Less than 2% counties had annual wildfire $PM_{2.5} > 1 \mu g/m^3$ before 2015 versus **34%** in 2020-2022.

Population growth & ageing

- 11.7%** increase in US total population since 2006
- 51% of counties show population increase
- 65+ increase from 16.4% to **23.1%**

Baseline mortality rate

- 86%** of counties show an average 8% decrease in baseline rate.
- 14%** of counties show an average 4% increase in baseline rate.

Hazard ratio (HR) for all source versus wildfire $PM_{2.5}$

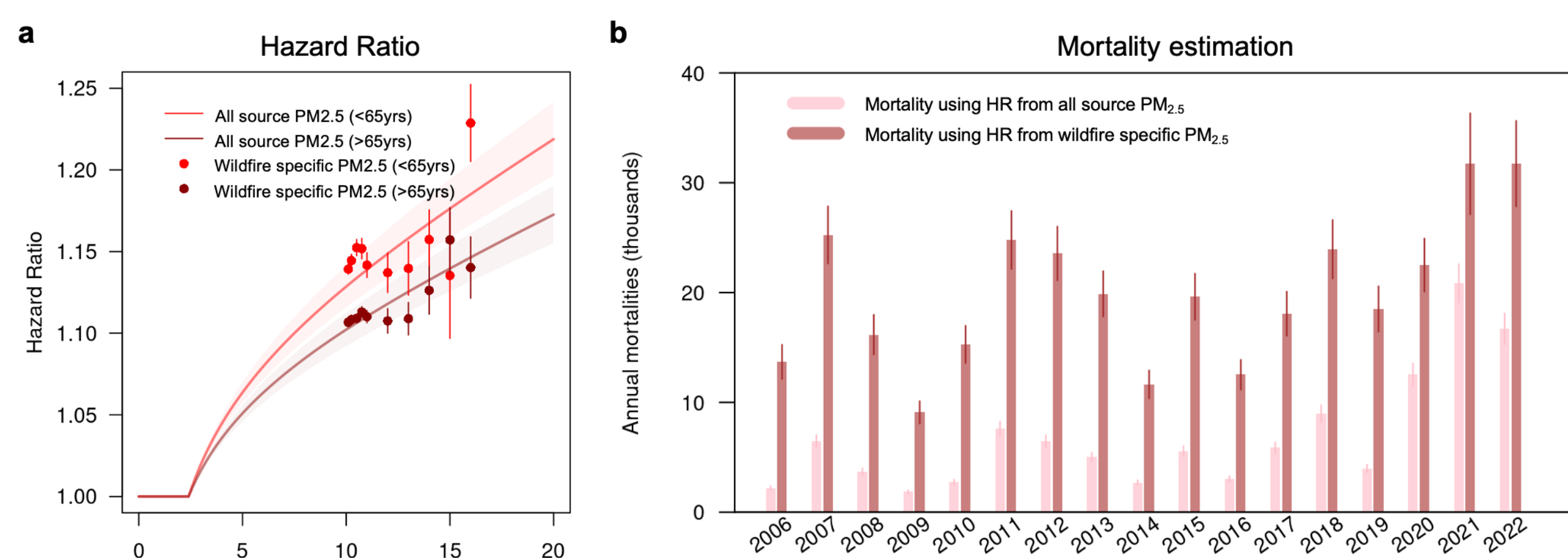


Figure 2. Hazard ratio and mortality estimations for wildfire $PM_{2.5}$. (a) Comparison between all source (Burnett et al., 2018) versus wildfire hazard ratio (Qiu et al., submitted); (b) annual mortality (in thousands) calculated using hazard ratio from all source $PM_{2.5}$ (light link) and hazard ratio from wildfire specific $PM_{2.5}$ (dark pink).

- HR for wildfire $PM_{2.5}$ shows **higher sensitivity** at low concentrations ($< 1 \mu g/m^3$) for all age groups, and high concentrations ($> 6 \mu g/m^3$) for ≤ 65 years old group.
- On average mortality estimations using HR for wildfire $PM_{2.5}$ is **3 times higher** than estimations using HR from all source $PM_{2.5}$. The difference is smaller in recent years due to 1) increased sensitivity of HR from all source $PM_{2.5}$ at lower concentrations; 2) constant HR for wildfire $PM_{2.5} > 6 \mu g/m^3$.

Contributions from socio-demographic factors

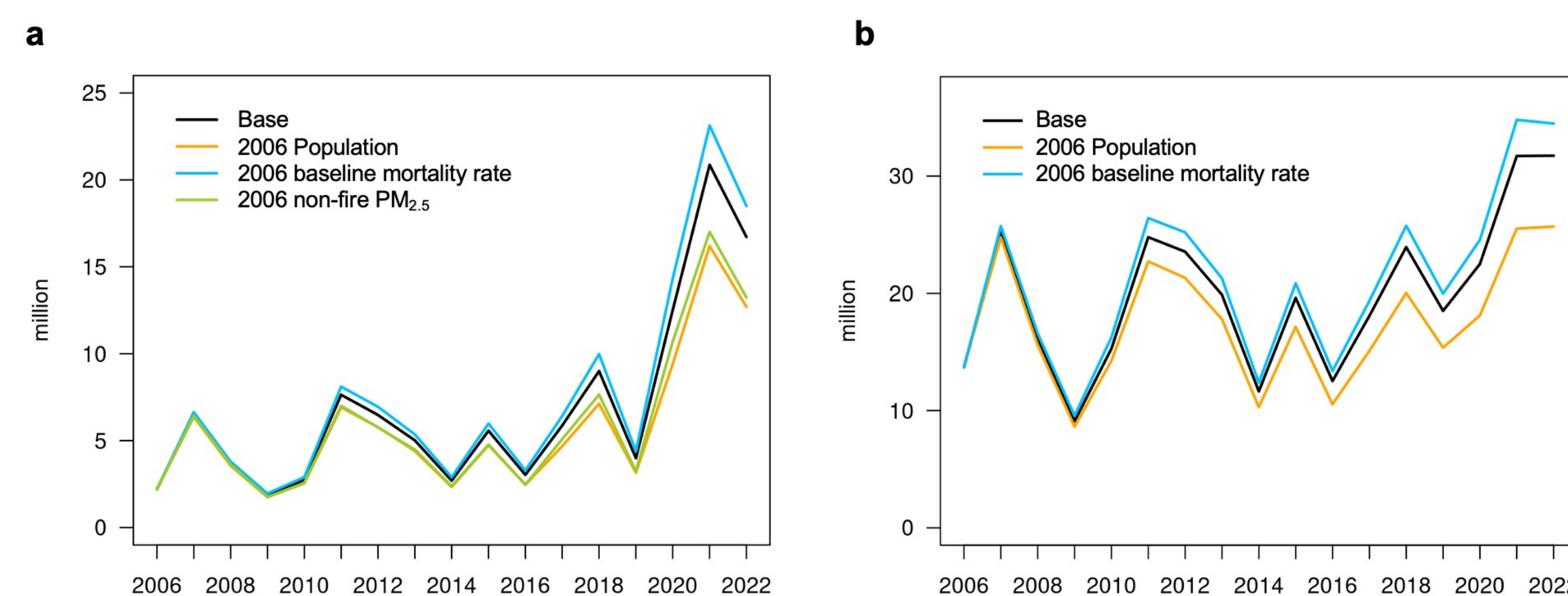


Figure 3. Contribution of socio-demographic factors to mortality burden of wildfire $PM_{2.5}$. (a) Mortality attributable to wildfire $PM_{2.5}$ from 2006-2022 with all factors varying (black), with 2006 population (orange), with 2006 baseline mortality rate (blue), with 2006 background $PM_{2.5}$ (green) calculated using HR for all source $PM_{2.5}$; (b) same as (a) but mortality calculated based on HR for wildfire $PM_{2.5}$.

- Cumulative mortality due to wildfire $PM_{2.5}$ during 2006-2022: 116,419 (panel a); 337,965 (panel b)
- Increase/ageing of population contributed to **17% increase** in of total mortalities.
- Decrease in baseline mortality rate contributed to **9% reduction** in total mortalities.
- Decrease in background $PM_{2.5}$ contributed to **14% increase** in total mortalities (**higher sensitivity to $PM_{2.5}$ increase at lower background $PM_{2.5}$ concentrations!**)

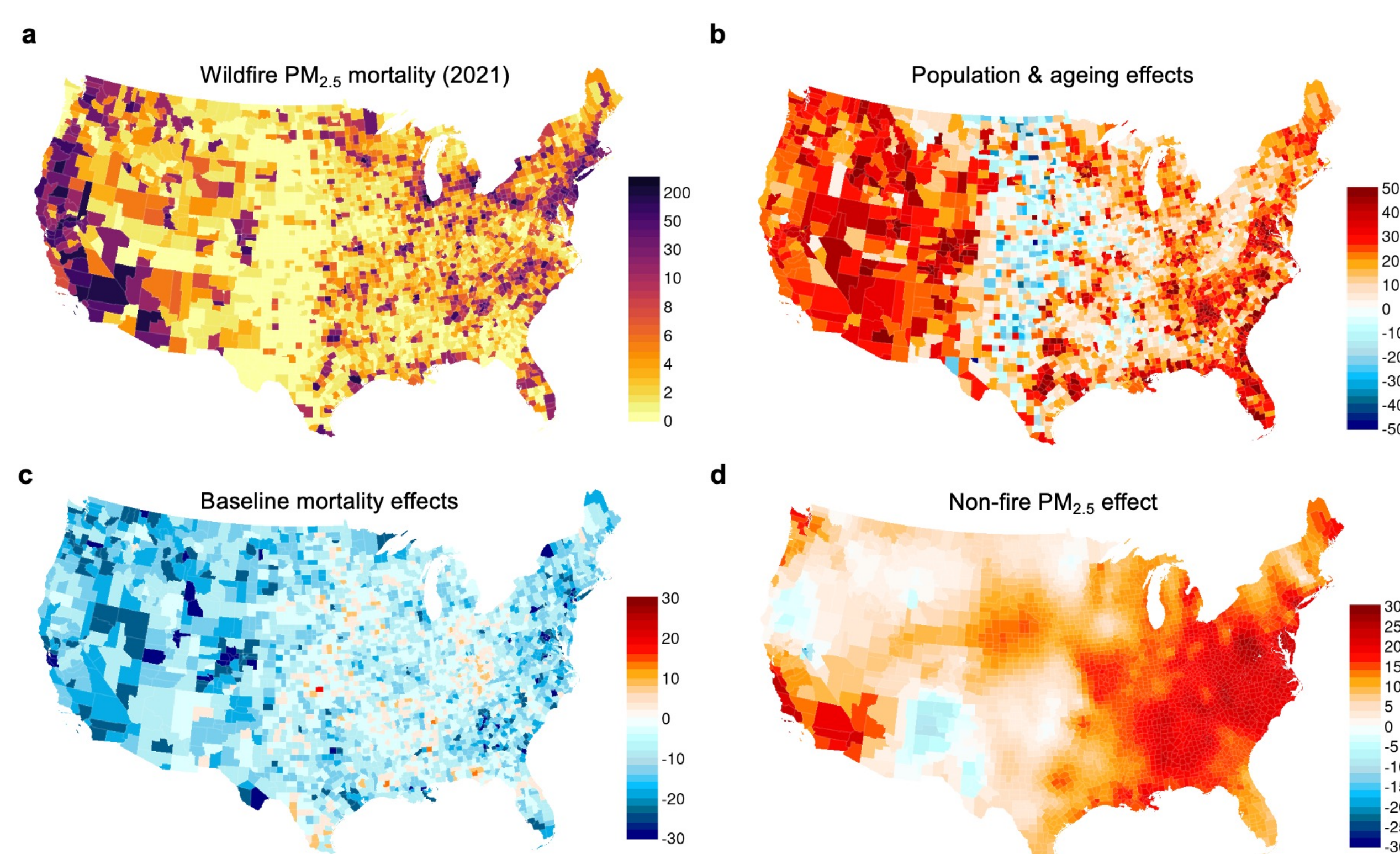


Figure 4. Contribution of socio-demographic factors to mortality burden of wildfire $PM_{2.5}$ at the county level in 2021. (a) Mortality attributable to wildfire $PM_{2.5}$ in 2021. (b-c) percent changes in mortality relative to those with each factor fixed at the 2006 level.

Sensitivity to spatial resolution of baseline mortality rate

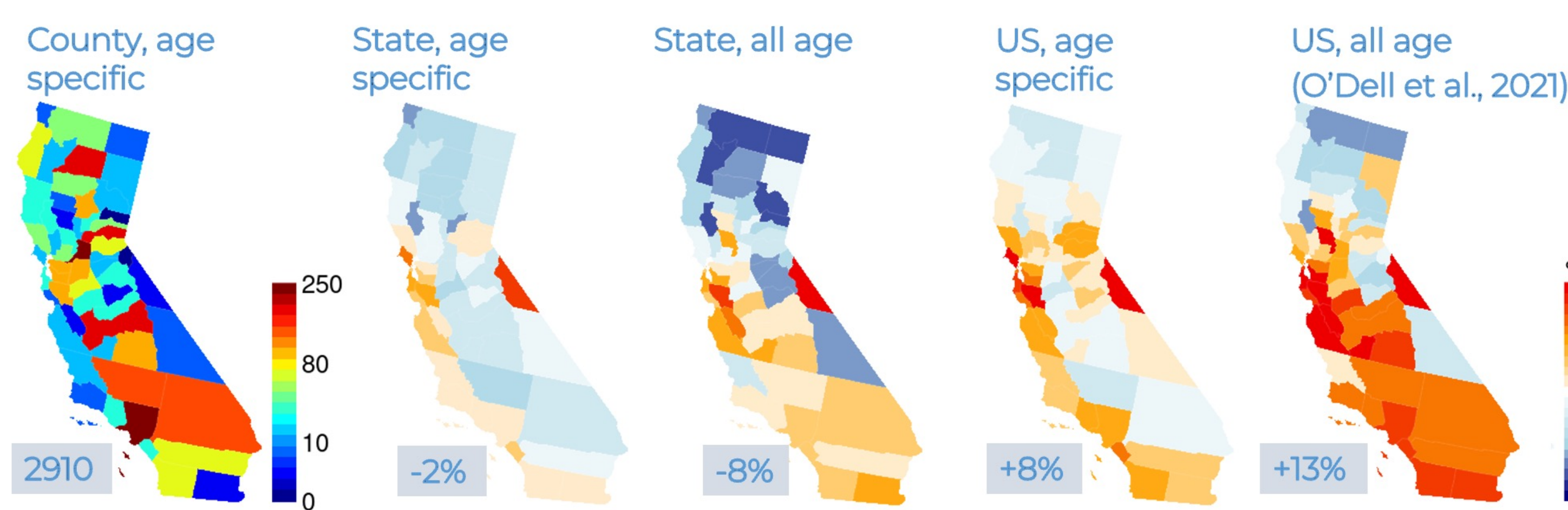


Figure 5. The estimated mortality burden due to wildfire $PM_{2.5}$ in California in 2021 using different spatial resolution of baseline mortality rate. From left to right, total mortality using county-level & age specific baseline mortality rate, % differences when using state-level & age specific, using state level all age, using US average & age specific, and US average & all age rate.

Take-aways

- The estimated mortality burden of wildfires is **~3 times higher** using hazard ratio for wildfire specific $PM_{2.5}$ versus that for all source $PM_{2.5}$.
- Changing socio-demographic factors **play important/different roles** in shaping the $PM_{2.5}$ mortality burden from wildfires at the county level.
- Wildfires are becoming a major source of air pollution that is increasing premature mortalities.
- Both **air pollutant emission controls** and **climate mitigation** are needed to reduce the $PM_{2.5}$ mortality burden in the US.

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Contact: yuanyux@Princeton.edu