

# Spatial-temporal analysis of particulate exposure in those experiencing homelessness compared to the housed population in Seattle, WA

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## Significances

**200+ years of healthy life**

would be saved for Seattle's homeless population if they were housed — even in the lowest-income neighborhoods

**≈ 0.55 μg/m<sup>3</sup> (air quality measure, lower is better)**

Higher PM<sub>2.5</sub> at tent encampments than housed tax lots every year — driven by encampment clearances forcing unhoused residents into high-pollution corridors

**7–12% more Disability-Adjusted Life Years (DALYs)**

The first quantitative study to translate PM<sub>2.5</sub> exposure disparities into attributable disease burden across housed, sheltered, and unsheltered populations — statistically significant at the location level

## Abstract

This study provides the first quantitative comparison of sustained PM<sub>2.5</sub> exposure and attributable health burden across housed, sheltered, and unsheltered populations within a single U.S. city. Tent encampments in Seattle are systematically located in the city's highest-pollution corridors ≈0.55 μg/m<sup>3</sup> above housed tax lots across all six study years. Translating this exposure gap into health consequences, unhoused individuals accumulate 7–11% more cumulative PM<sub>2.5</sub>-attributable DALYs over 32 years (1990–2021) than housed residents, with uncertainty intervals excluding zero. We conclude that homelessness is fundamentally an environmental justice crisis, and stable indoor housing must be recognized as a material reduction in environmental risk.

## Background

- PM<sub>2.5</sub> linked to IHD, stroke, lung cancer, LRI, type 2 diabetes, COPD — a leading cause of preventable mortality

- Marginalized groups bear disproportionate air pollution burden; unhoused populations nearly absent from this literature

- 700,000+ unhoused on any night in the U.S.; ~300,000 in tents, parks, streets

- No prior study has quantified PM<sub>2.5</sub>-attributable disease burden for unhoused vs. housed within the same city

## Research Question

- Does housing status, independent of neighborhood income, produce a spatially structured PM<sub>2.5</sub> exposure gap in Seattle?
- Does that gap translate into a measurable excess of PM<sub>2.5</sub>-attributable health consequences for sheltered and unsheltered residents?

## Data & Sample

> **Setting:** Seattle, WA (King County), 2016–2021 for exposure analysis; 1990–2021 for chronic DALY calculation.

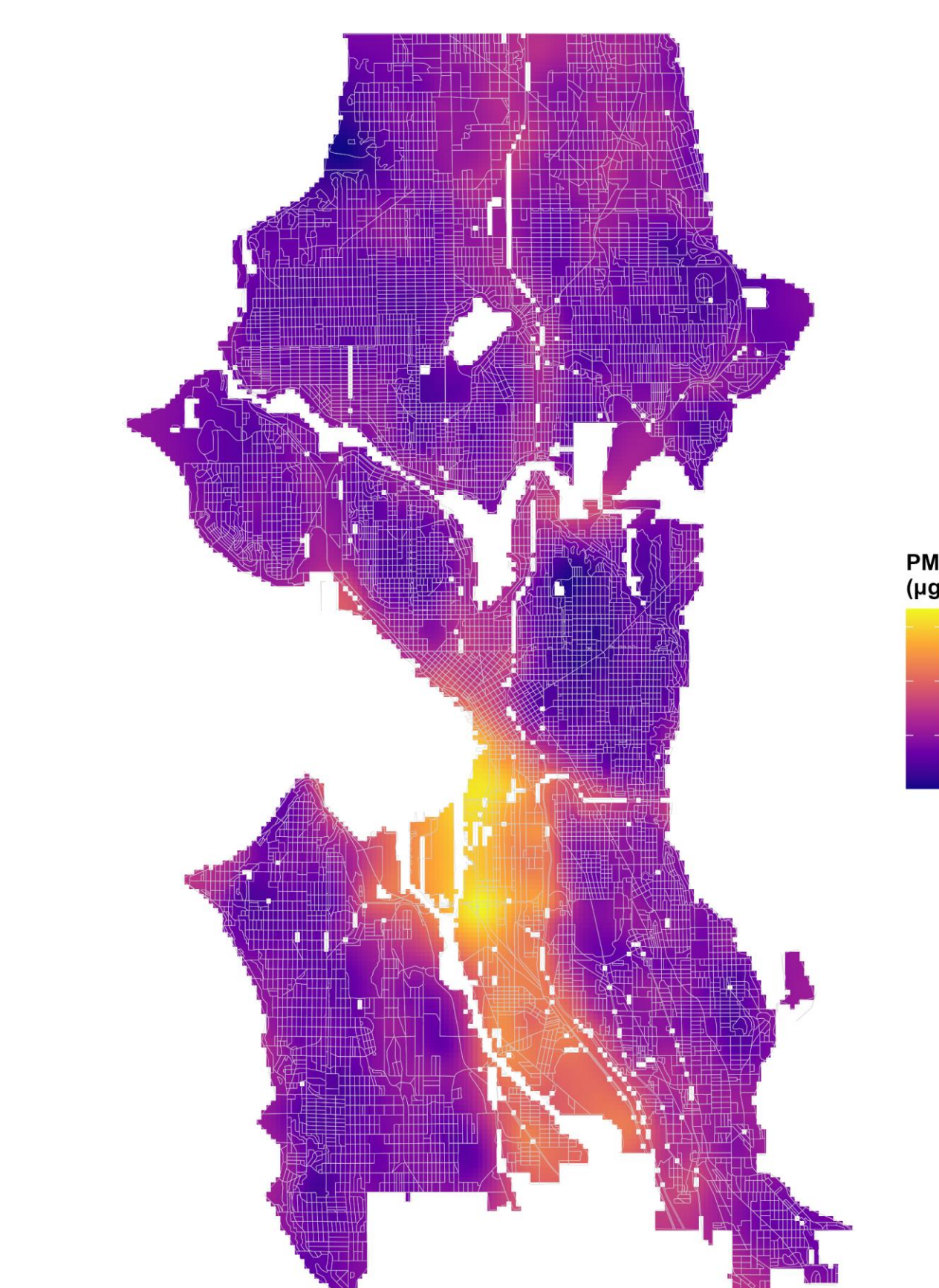
**716 Housed tax lots** — stratified random sample from Seattle parcels (4×4 density/parcel strata × 45 blocks × 1 lot)

**675 Tent encampment sites** — ETS REACH street-outreach geocoded database

**125 Shelters / transitional housing** — Sutton et al. 2026

**32 yr Exposure window** for DALYs — 1990–2021 long-term mean

PM<sub>2.5</sub> Exposure Surface Map (2016–2021)  
Autokriging interpolation (Skrjvar) | Grid: 100m | Locations within Seattle boundary



## Spatial disparity of air pollution directly translates into an unequal burden of disease

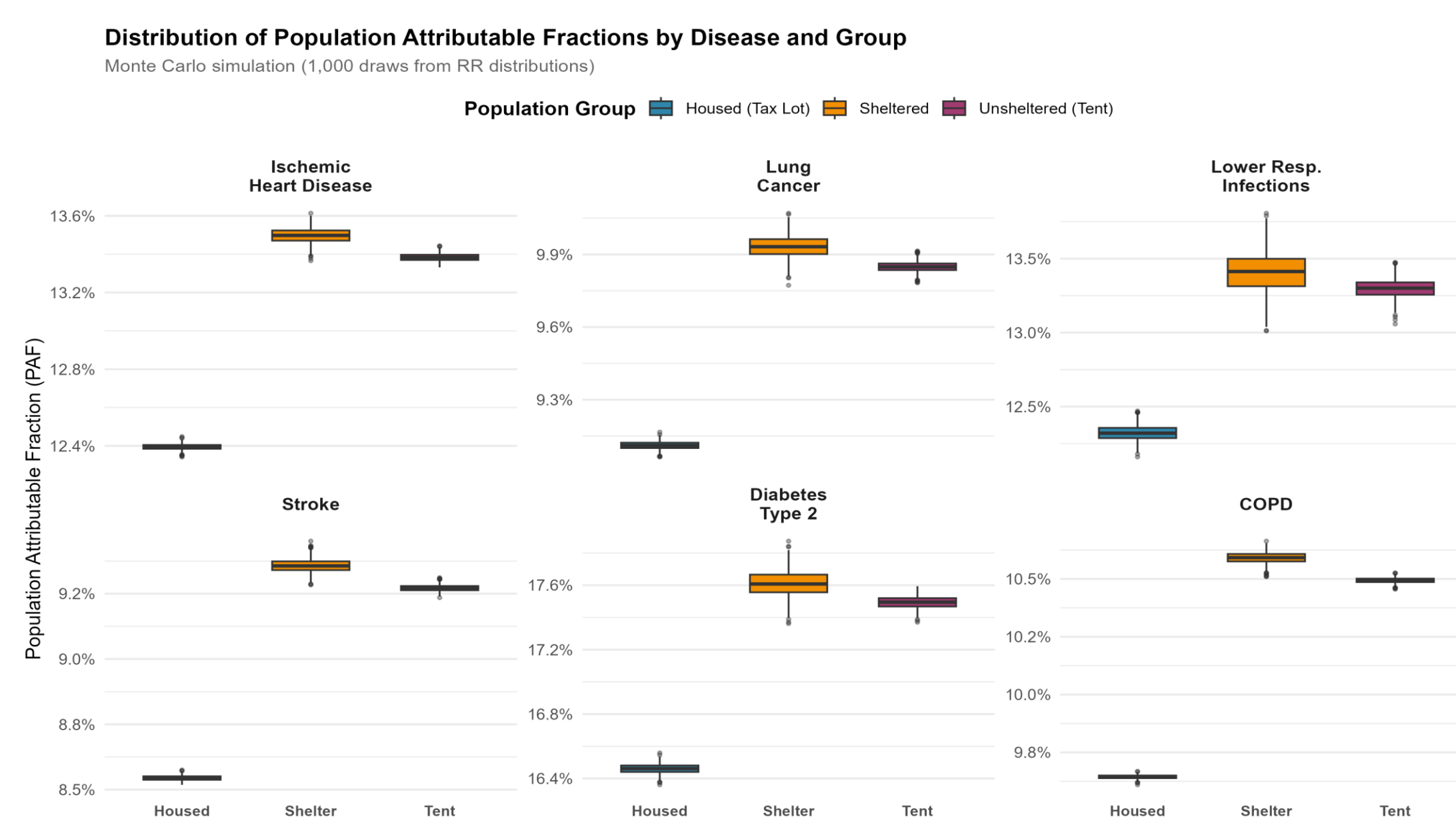
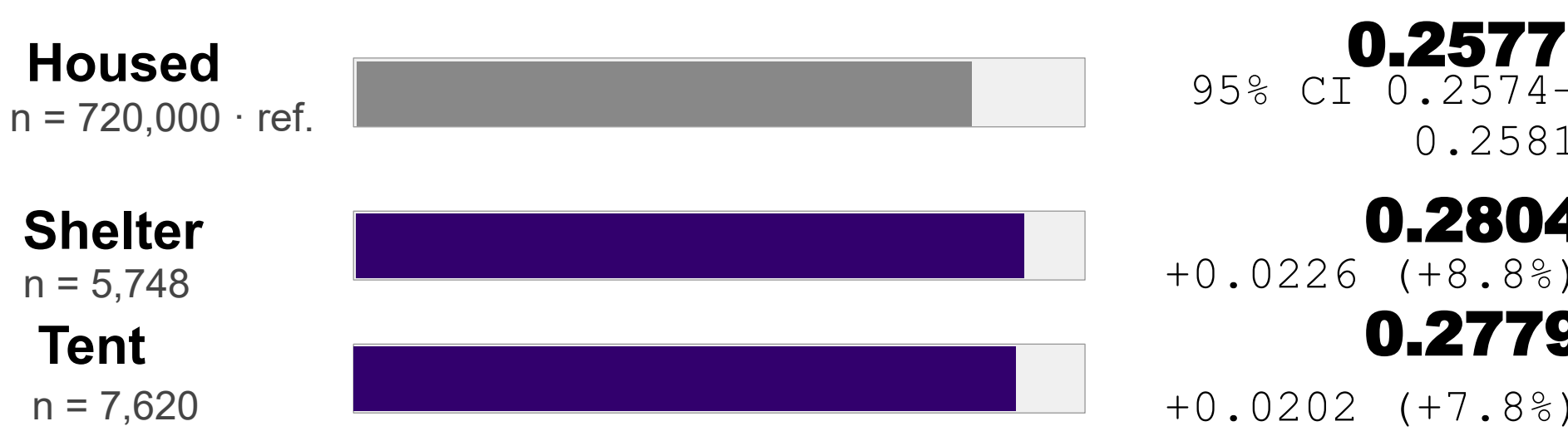


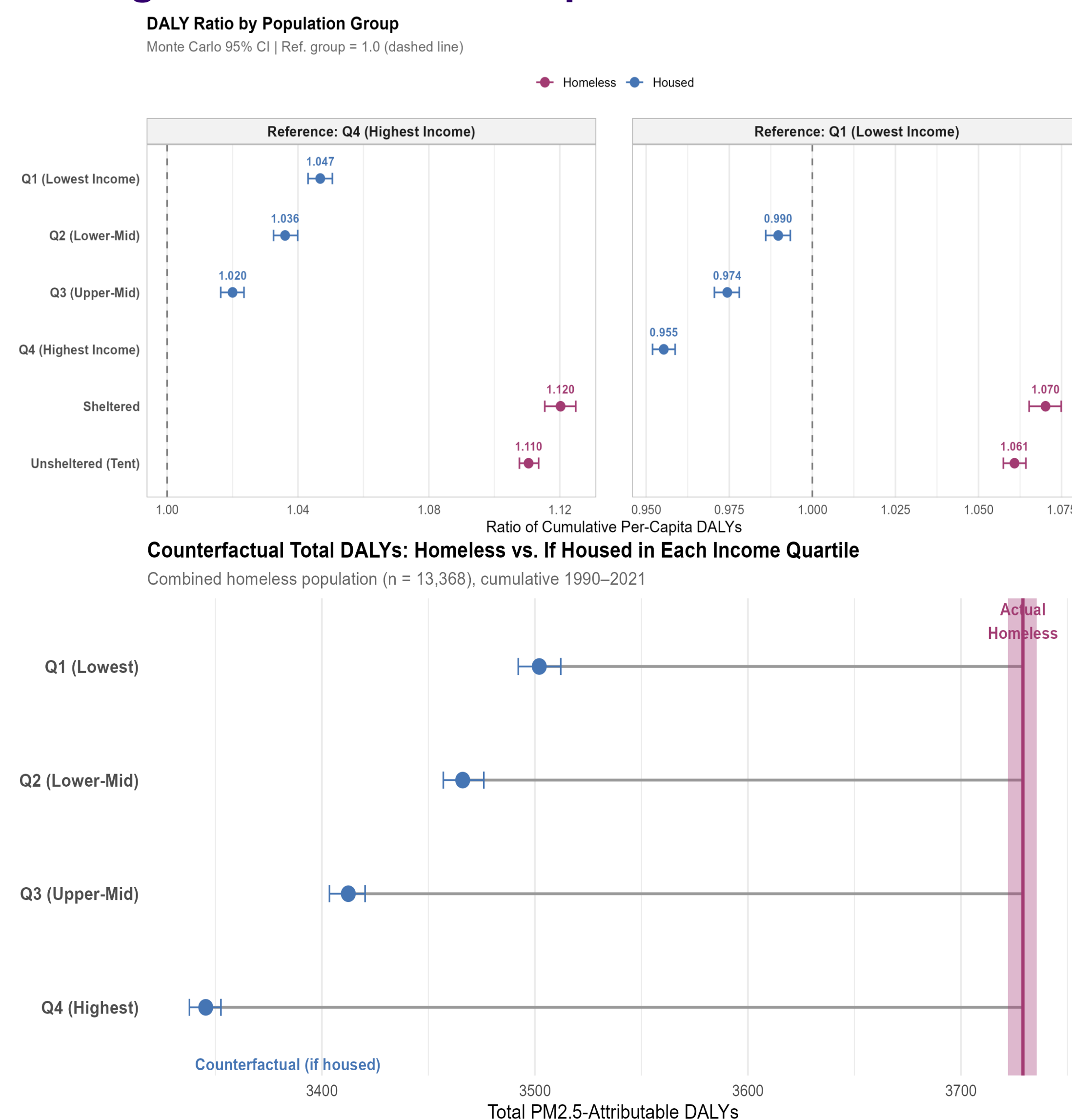
Fig. 2 — Population attributable fractions by disease and group (1,000 Monte Carlo draws from GBD RR uncertainty bounds). Shelter and tent PAFs consistently exceed housed across all six disease pathways.

## Cumulative per-capita PM<sub>2.5</sub>-attributable DALYs, 1990–2021

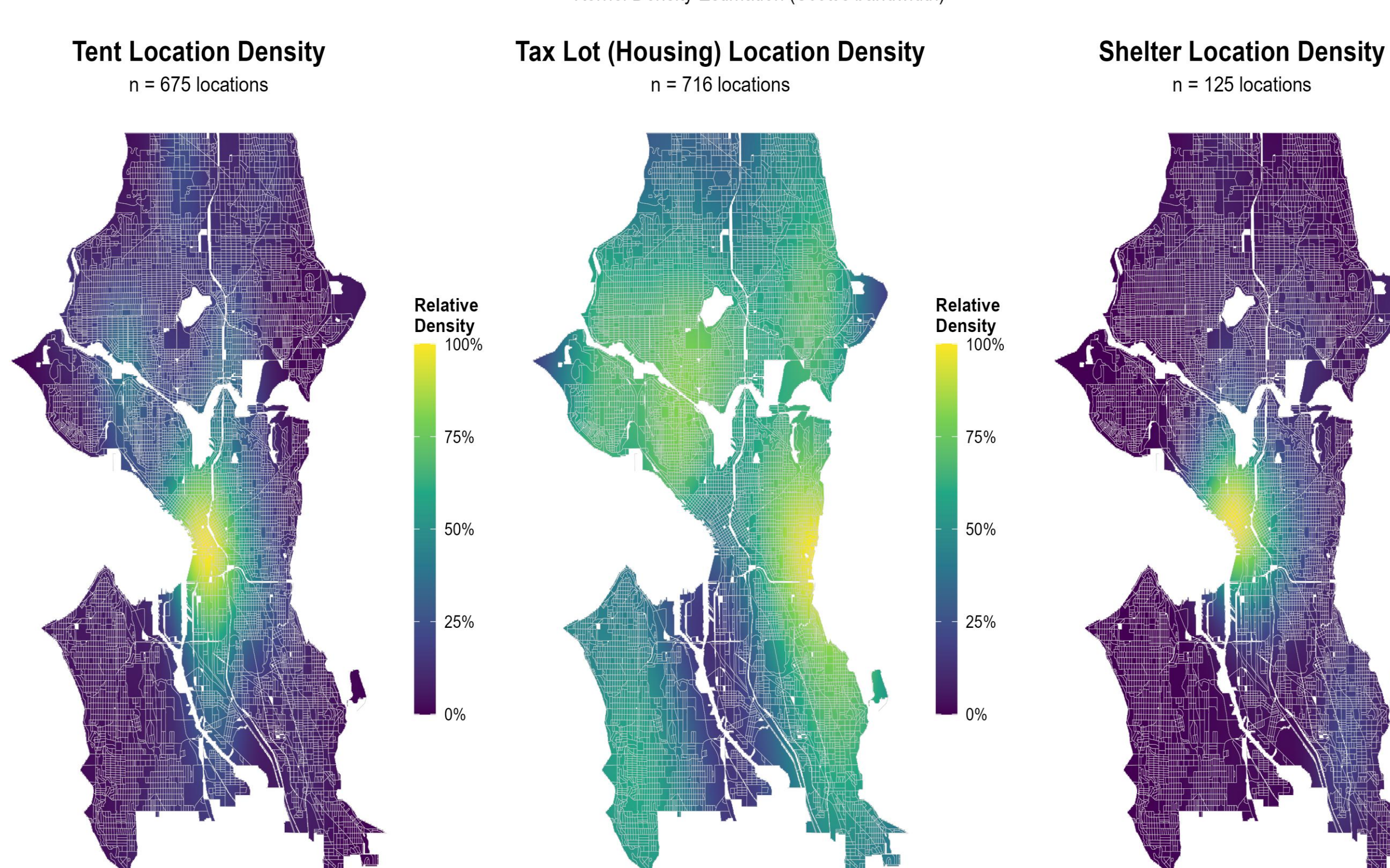


Bars scaled 0 → 0.305. 95% CI from 1,000-draw Monte Carlo over GBD risk curves; between-group differences computed within draw. All CIs exclude zero.

## Neighborhood income expands the difference



## Location Density Comparison: Tent vs Tax Lot vs Shelter



## Methods

**Marked Poisson point process** — cross G-functions and mark correlation  $\rho(r)$  tested against Complete Spatial Randomness

**DALY calculation** — GBD 2021 risk curves → location-level RR → population-weighted  $E(RR)$  → PAF × WA baseline DALY rate, summed across 6 disease pathways

$$E(RR_{g,d}) = \int_{lower}^{upper} f_{rr}(e)p(e)de$$

$$PAF_{g,d} = \frac{E(RR_{g,d}) - 1}{E(RR_{g,d})}$$

**Uncertainty** — 1,000 Monte Carlo draws from GBD RR bounds; excess DALYs computed within each draw to preserve group correlation

## Seattle's geography of housing insecurity is also its geography of disproportionate environmental hazard:

Unhoused locations concentrate in the high-exposure corridor; housed lots spread through lower-exposure residential areas.

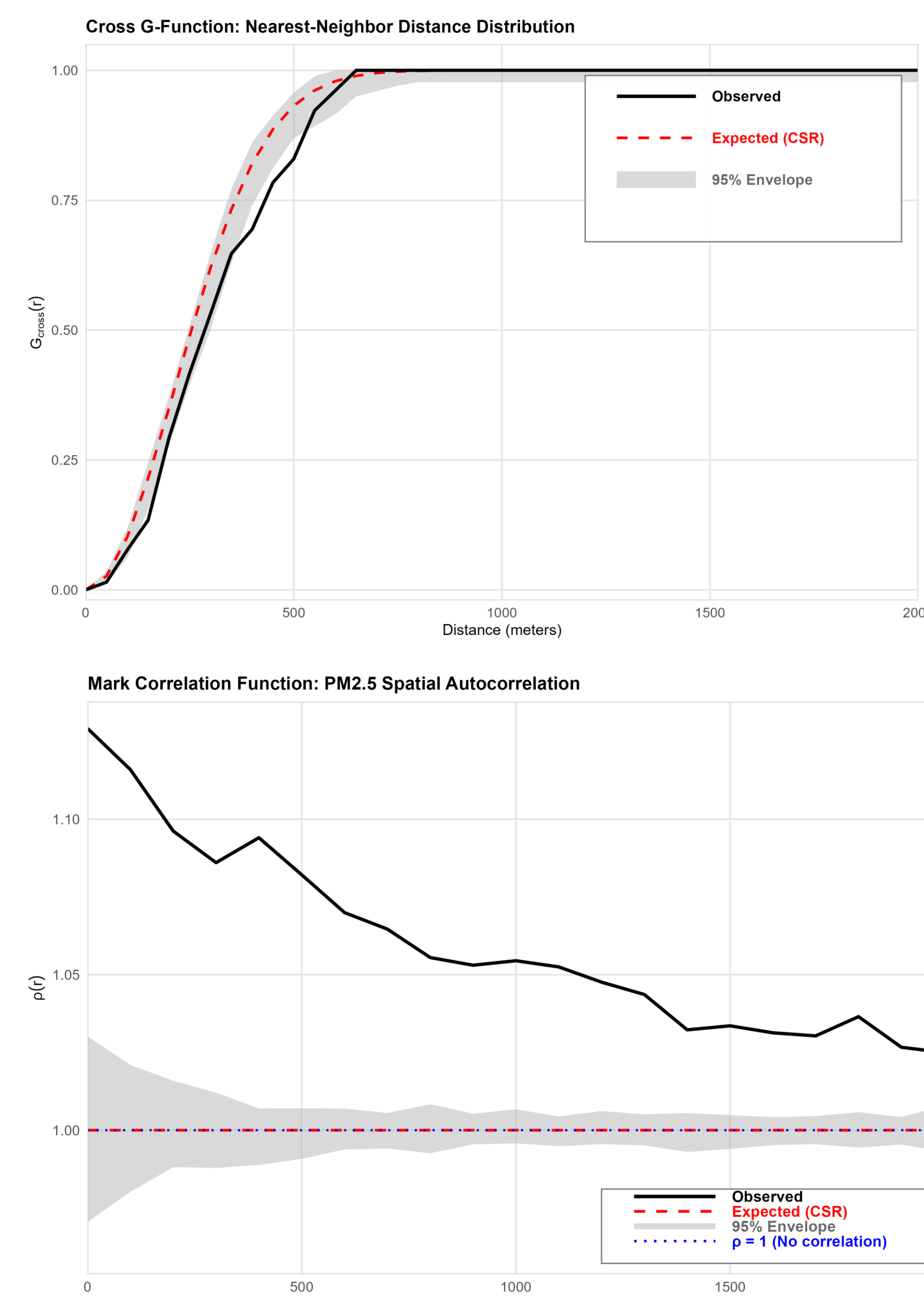


Fig. 1 — Spatial diagnostic functions (Cross G) and PM<sub>2.5</sub> mark correlation. All  $p < 0.005$  vs. CSR.

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