Air Pollution Injustice: Mapping PM2.5 Levels Across Puget Sound

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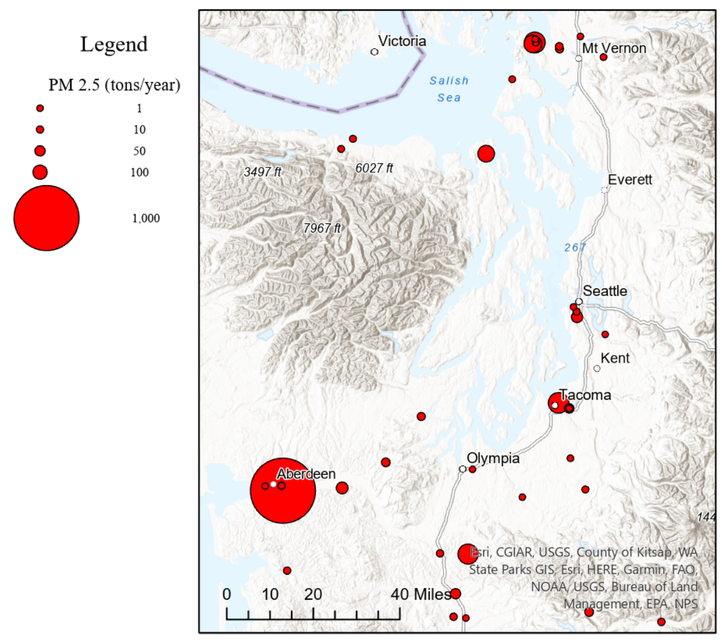
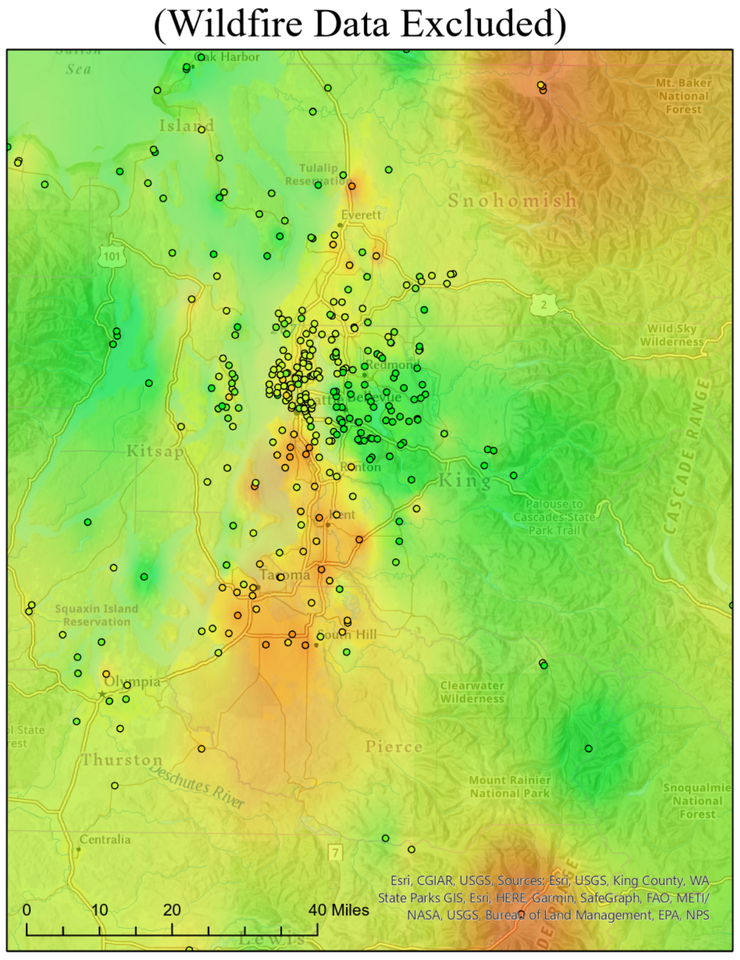
Abstract:
Since US national standards for fine particulate matter, or PM2.5, were first established in 1997, PM2.5 concentration has become an important indicator of air quality. PM2.5 is a particularly dangerous air pollutant because it penetrates and deposits deep into the lungs, causing severe health impacts. Exposure to PM2.5 can lead to premature death, respiratory disease, cardiovascular disease, and has been associated with cognitive decline and an increased risk of developing dementia[1]. Previous research has shown that lower-income groups and racial and ethnic minority populations in the US are exposed to higher levels of PM2.5 and are at a higher risk of premature death due to this exposure[2]. PM2.5 levels in the Puget Sound area are generally low relative to the rest of the country, but have been increasing in recent years due to a rapid increase in wildfires caused by climate change. This study examines how concentrations of PM2.5 were distributed across the Puget Sound region in 2022, and the correlation between severity of exposure and race, ethnicity, and income.

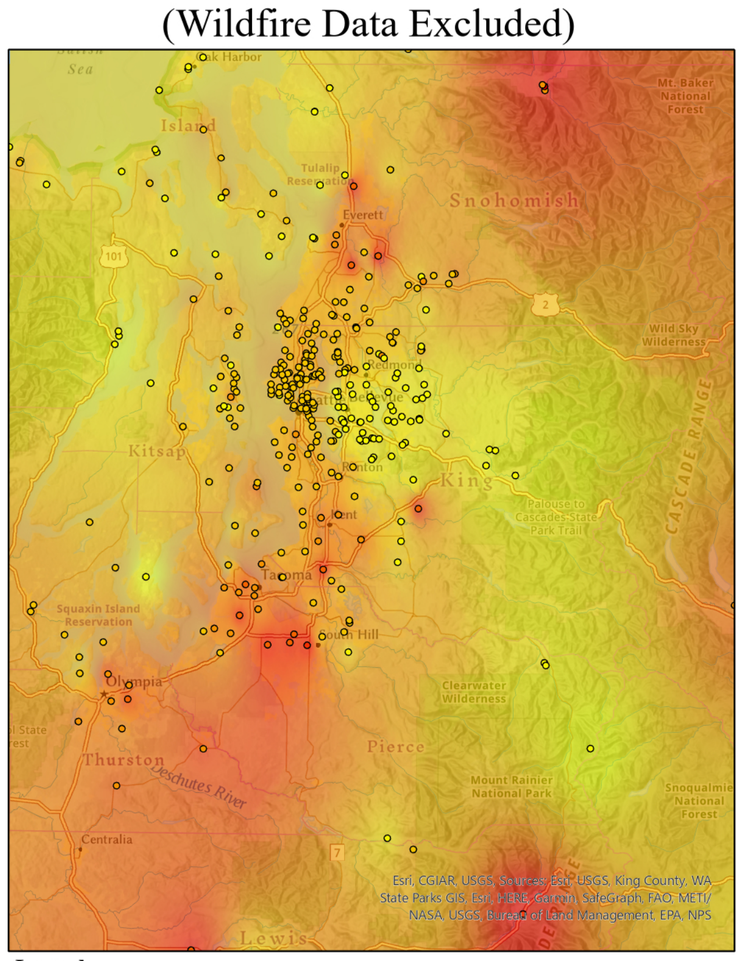
Major PM2.5 Point Sources in 2020



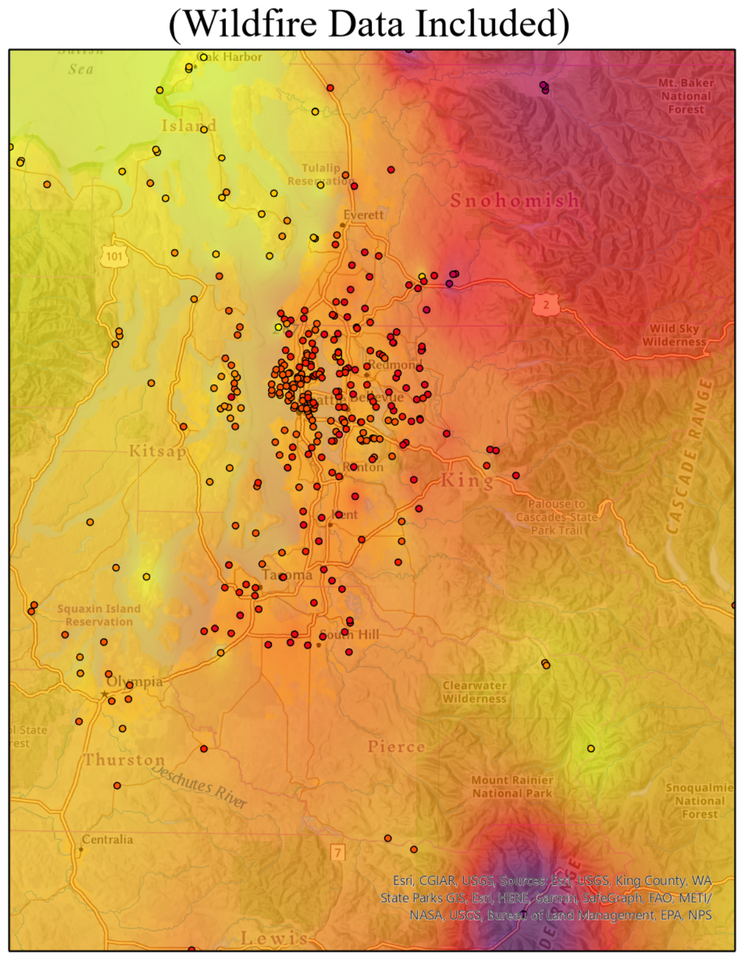
Annual Average PM2.5 Concentrations in 2022 (Wildfire Data Excluded)

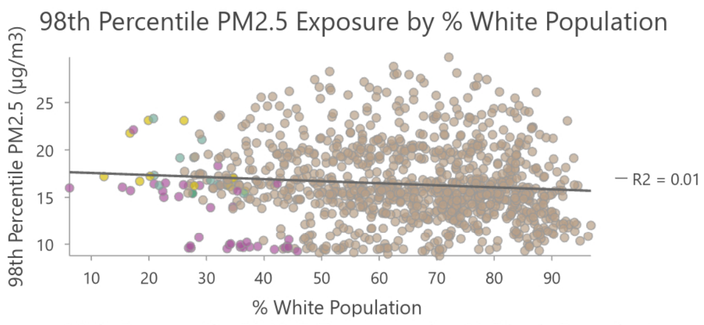


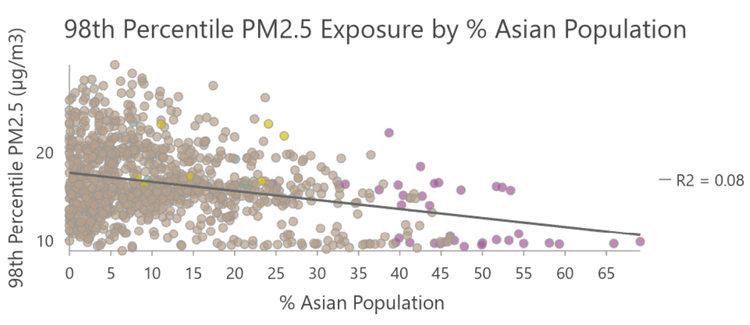
98th Percentile PM2.5 Concentrations in 2022 (Wildfire Data Excluded)

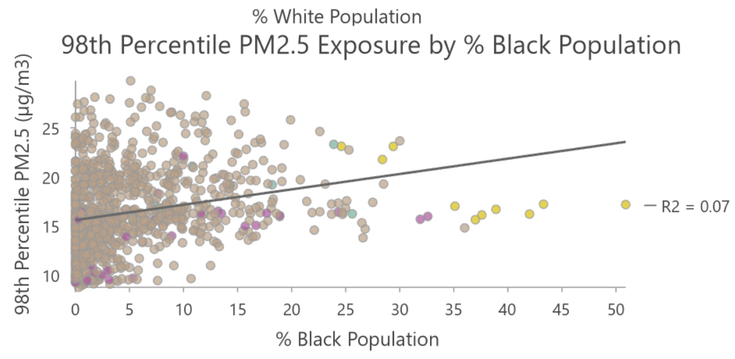


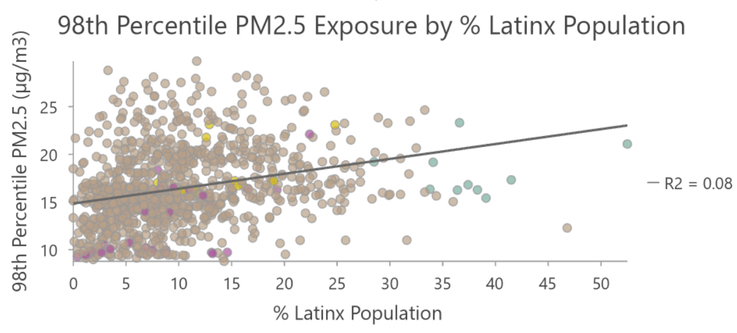
98th Percentile PM2.5 Concentrations in 2022 (Wildfire Data Included)

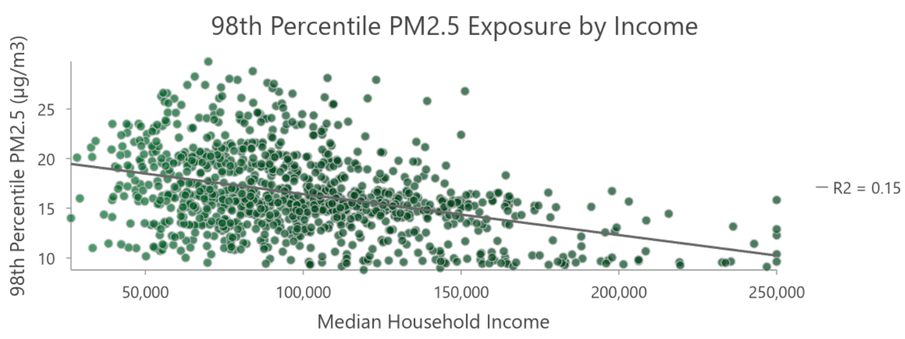












Methods:
1) Imported PSCAA 2022 air quality data as csv files
2) Used XY table to point to map monitoring locations
3) Customized symbology for consistency across maps
4) Imported ACS Income and Race Layers to all maps
5) Used Export Features to limit the extent of the ACS Layers
6) Used Clip to match extents across ACS layers
7) Ran IDW Interpolation on the PSCAA points
8) Ran Zonal Statistics as Table for all 3 PSCAA data maps, using the IDW layer as input to find the mean PM2.5 concentrations for each ACS tract
9) Used Join Field to transfer the mean PM2.5 value to the attribute tables of both ACS layers
10) Imported EPA major point source emission data as an Excel file and assigned proportional symbology

Results:
Examining the map of Annual Average PM2.5 concentrations, the entire range of data falls under the EPA standard of 12 µg/m3. However, there are several zones in the 98th percentile data with wildfires excluded where the EPA limit of 35µg/m3 was exceeded, up to 37.19µg/m3. When factoring in the wildfire data, the results are extremely concerning. Roughly 23% of the monitoring locations recorded PM2.5 values over the EPA limit, with values as high as 109.79µg/m3. Examining the scatter plots reveals several notable trends in the data. There is a strong negative correlation between median household income and 98th percentile PM2.5 concentrations, indicating that lower-income households are more exposed to high levels of PM2.5, putting them at higher risk for related health complications. There is a strong positive correlation between PM2.5 levels and areas with greater Black or Latinx populations, indicating that Black and Latinx communities in the Puget Sound area are disproportionately exposed to high concentrations of PM2.5, putting them at a higher risk for health complications as well. There is a negative correlation between PM2.5 levels and areas with greater Asian populations, indicating that Asian communities in the Puget Sound tend to be somewhat less exposed to hazardous levels of PM2.5. There appears to be no significant correlation between PM2.5 levels and areas with greater White populations, which I believe is due to the fact that this area is majority White, and the wide variation of income levels among White households.

Conclusion:
The 98th percentile PM2.5 statistics revealed through this analysis are particularly troubling because previous research has established that even short-term exposures to high concentrations of PM2.5 can lead to severe health impacts[1]. Moreover, the true 98th percentile PM2.5 concentrations with wildfire data included revealed that PM2.5 levels are already reaching extremely hazardous levels in many parts of the Puget Sound Area. This is very concerning, as the impacts of climate change will only continue to increase the frequency and severity of wildfires in this area in the future. Furthermore, the correlations I observed between PM2.5 levels and demographic exposures are clearly indicative of environmental injustice, demonstrating an urgent need for greater enforcement and regulation of environmental policies in low-income areas and in communities with larger Black and Latinx populations.

Data Sources/ Bibliography:
Puget Sound Clean Air Agency (PSCAA), Air Quality Sensor Map, 2022.
American Community Survey (ACS), Median Household Income Variables, ArcGIS Online, 2022.
American Community Survey (ACS), Race and Hispanic Origin Variables, ArcGIS Online, 2022.
Washington State Department of Ecology, Air Quality Major Point Source Emissions, 2020.
[1] Han, Y. and Zhu, T., 2015. Health effects of fine particles (PM 2.5) in ambient air.
[2] Jbaily A, Zhou X, Liu J, Lee TH, Kamareddine L, Verguet S, Dominici F. Air pollution exposure disparities across US population and income groups. Nature. 2022 Jan;601(7892):228-233. doi: 10.1038/s41586-021-04190-y. Epub 2022 Jan 12. PMID: 35022594.