Minimizing heatwave risk through an equitable distribution of solar panels

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1. Introduction

2. Methods and Data

In this section we review the data we collected for the City of Chicago and the methods we used to cluster Chicago's census tracts into priority areas for solar panel distribution. We used the hazard-exposure-vulnerability framework asserted by the International Panel on Climate Change (IPCC) to categorize the datasets used in this work [1, 2].

Table 1. Summary of curated data for the city of Chicago

Dataset	Risk Aspect Aspect	Spatial Resolution	Factor	Source
Temperature	Hazard	Community Area	Aggravating	[3]
Population density	Exposure	Census tract	Aggravating	[4]
Percent tree canopy	Vulnerability	Community area	Mitigating	[5]
Energy burden	Vulnerability	Census tract	Aggravating	[6]
Age	Vulnerability	Census Tract	Aggravating	[4]
Cooling centers	Vulnerability	Community Area	Mitigating	[4]
Social network	Vulnerability	Community Area	Mitigating	[4]
Crime rate	Vulnerability	Community Area	Aggravating	[4]
Percent qualified roof area	Vulnerability	Census Tract	Mitigating	[7]

2.1. Hazard

Hazards are the climate-related events the may lead to adverse outcomes for people, such as losses of life, function, property, infrastructure, and resources [1]. In this work, we focus on the risk of heat stress and the potential for heat-related deaths, for which temperature is the primary hazard. We gathered hourly temperature data for each community area in Chicago for the years 2000 to 2020 using the National Solar Radiation Database (NSRDB) [3]. In order to capture the temperature difference among Chicago's community areas during heatwaves, we set a temperature threshold of 32°C and filtered out the data below this threshold. We defined a heatwave temperature anomaly,

$$H_a = T_{ca} - T_{city}, \tag{1}$$

where T_{ca} is the temperature of the community area and T_{city} is the mean temperature of the city (i.e. the mean of all community areas), in celsius. We then took the mean of the hourly H_a to use in our clustering algorithm. Figure 2.1 shows the variations in temperature during heatwaves in Chicago.

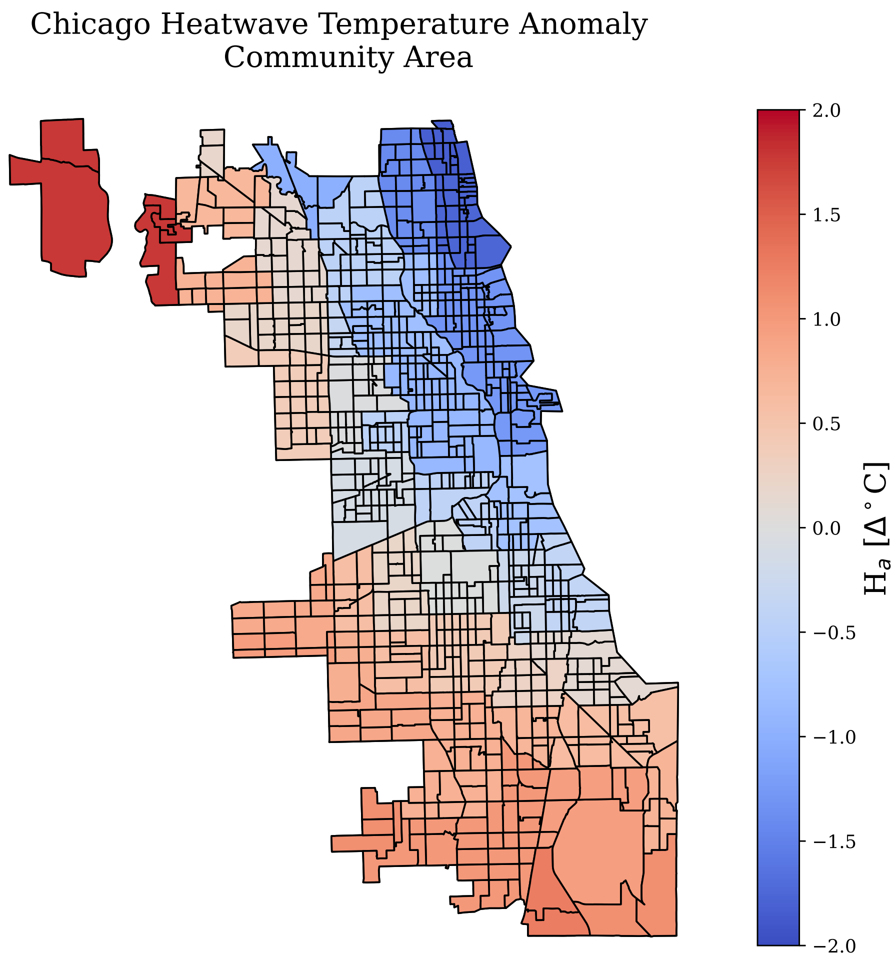


Figure 1. The temperature variations among community areas in Chicago during heatwaves. Higher values indicate warmer temperatures than the city mean temperature and lower values indicate cooler temperatures.

A greater H_a indicates regions that experience higher temperatures during heatwaves and lower a H_a indicates regions with lower heatwave temperatures. The region near O'Hare International Airport experiences the highest temperatures, nearly 2°C above the citywide average. The temperature anomalies are further adjusted by subtracting the minimum temperature difference such that the coolest area of the city has an $\bar{H}_a$ value of zero and other values indicate the temperature above this minimum value. This is done to ensure good behavior from the clustering process.

2.2. Exposure

Exposure is the presence of people or important assets in places that could be adversely affected by climate hazards [1].

2.3. Vulnerability

Vulnerabilities are the factors that predispose certain groups or areas to adverse outcomes. We consider several physical and social vulnerabilities.

2.3.1. Energy Burden Energy burden is the ratio of household energy costs to household income. We used data from Climate and Energy Justice Screening Tool (CEJST) to create a map of energy burden in Chicago [6]. Energy burden affects access to electricity, especially during heatwaves when demand and cost of electricity are highest. Rooftop solar panels can reduce energy costs and therefore improve access to cooling during heatwaves. Figure 2.3.1 shows the distribution of energy burden throughout Chicago.

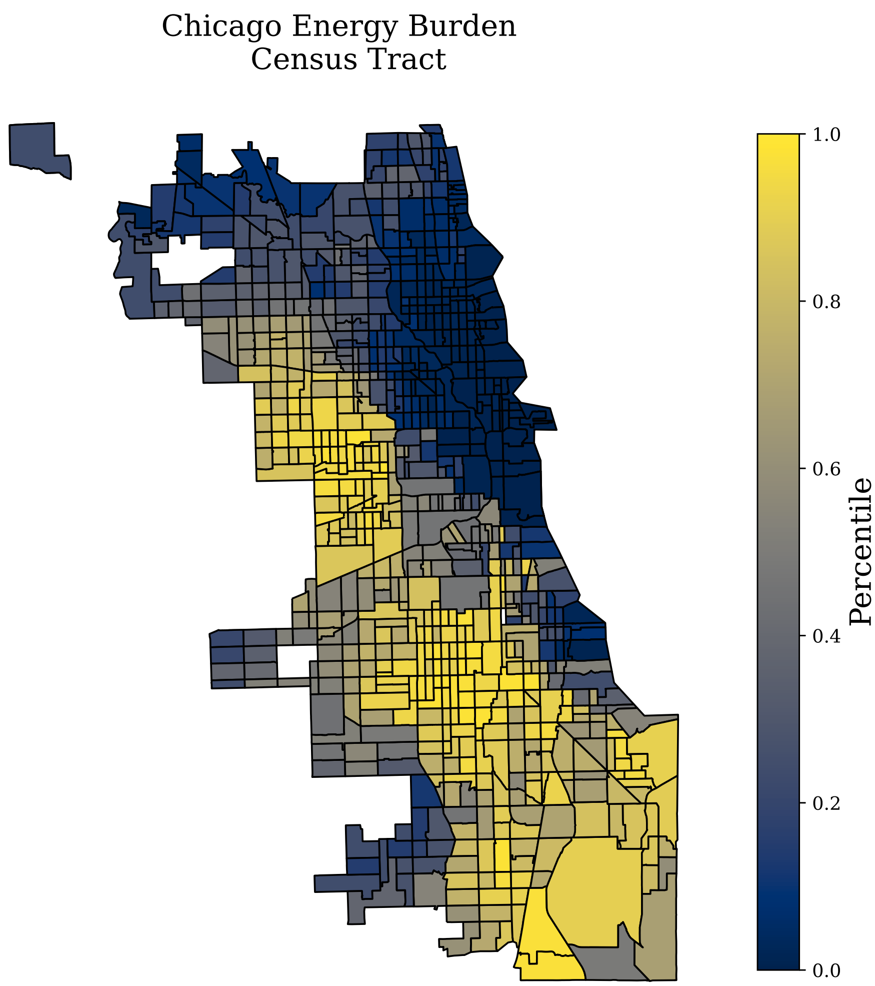


Figure 2. Energy burden throughout Chicago as a percentile. A region in the zeroth percentile has the least energy burden and a region in the 100th percentile has more energy burden than any other region.

2.3.2. Tree Canopy Urban tree cover effectively mitigate land surface temperatures in cities [8–10]. Tree canopy reduces temperature by preventing ground heat storage through shade and encouraging evapotranspiration [10]. Thus, areas with greater tree cover are less vulnerable heatwaves. Figure 2.3.2 shows the distribution of trees in Chicago from the Morton Arboretum Tree Census [5].

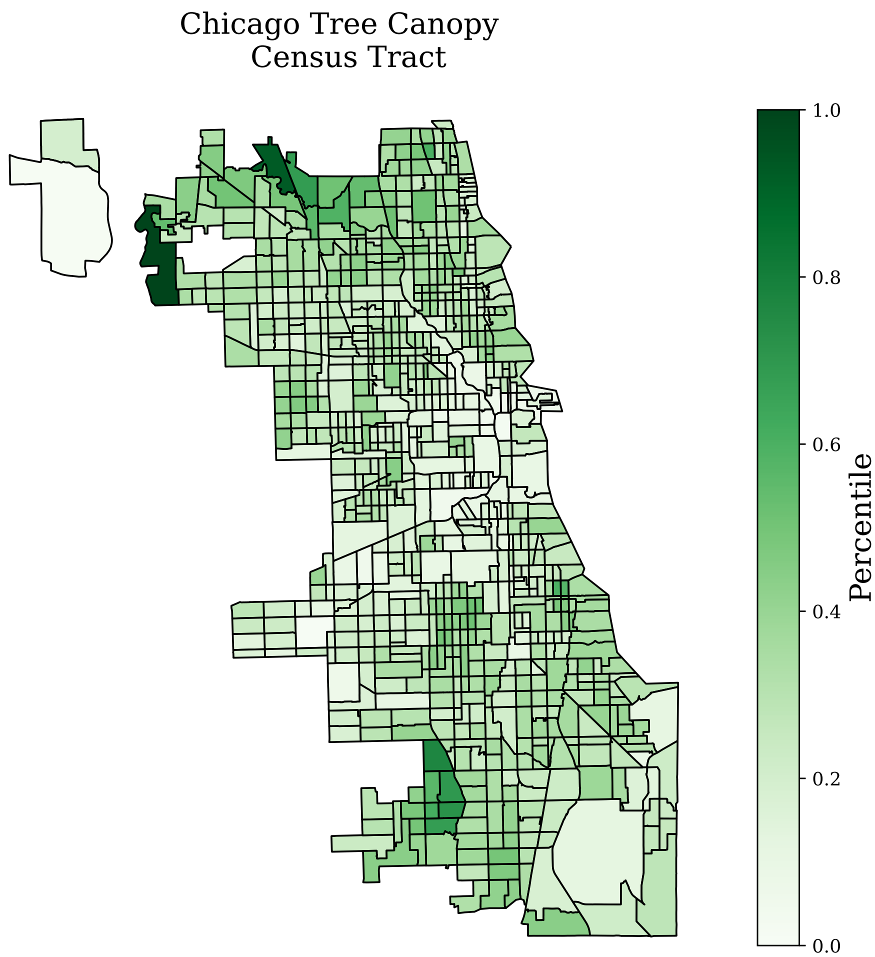
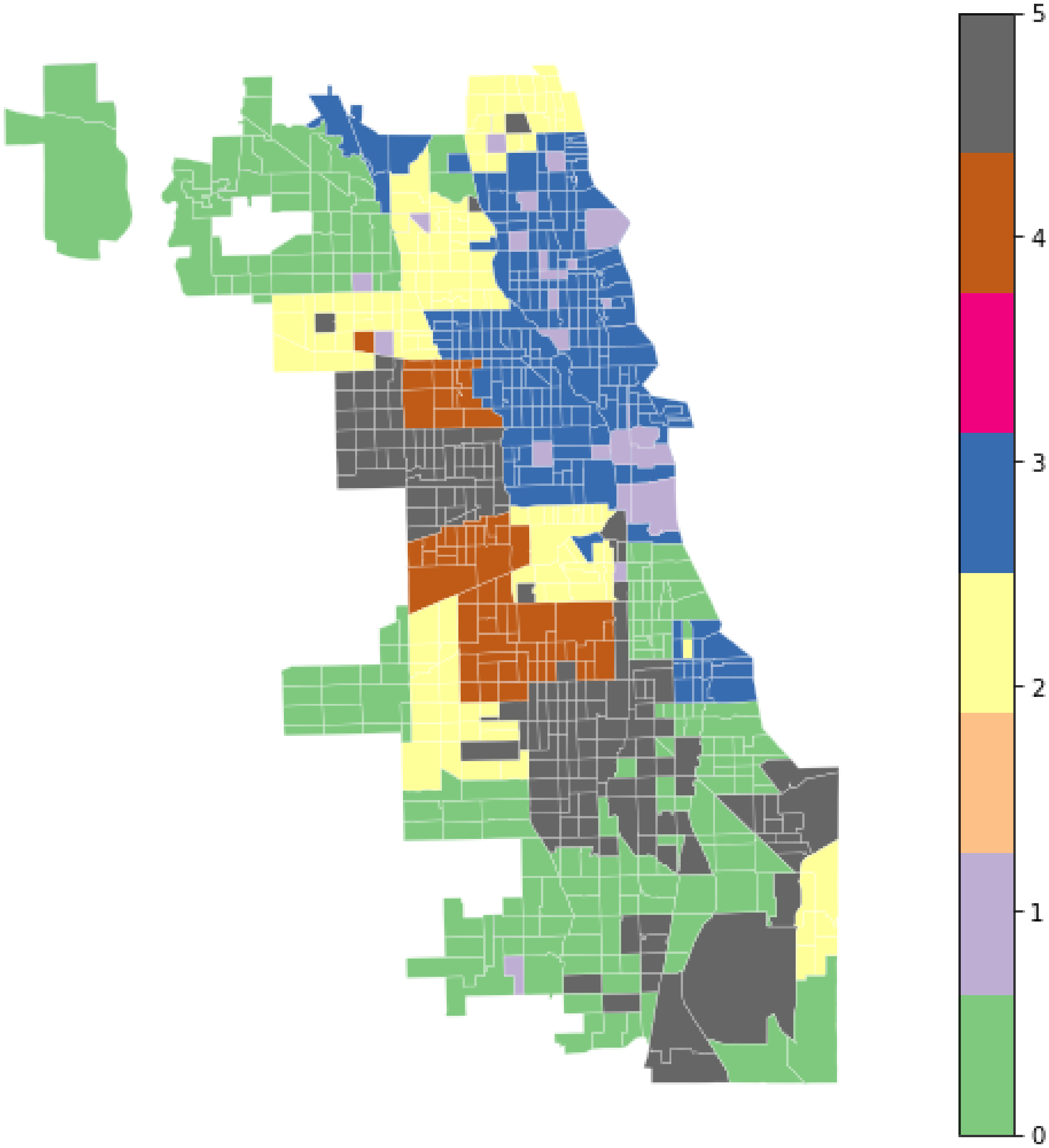


Figure 3. Distribution of trees in Chicago by percentile. A region in the zeroth percentile has the least tree canopy and a region in the 100th percentile has more tree cover than any other region.



3. Results

4. Discussion

5. Conclusion

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