Assessing Heat Risk in Chicago: A Spatial Climate Analysis

Climate Adaptation and Mitigation

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Question & Hypothesis

Question: How do green space distribution and socioeconomic status impact heat-related health risks in Chicago, considering the Urban Heat Island (UHI) effect?

Hypothesis: In Chicago, urban areas with less green space and lower socioeconomic status are anticipated to experience higher heat-related health risks due to the intensified Urban Heat Island (UHI) effect. This effect is exacerbated by increased impervious surfaces and reduced tree canopy coverage, leading to elevated temperatures and greater health risks.

Introduction & Background

Urban Heat Island (UHI) Effect: Chicago experiences a significant Urban Heat Island (UHI) effect.

- **Characteristics:** Elevated temperatures in urban areas compared to surrounding rural regions.
- **Causes:** Increased heat retention in built environments and reduced green spaces in regions most noticeable at night.

Impact of Urban Land Cover on Nighttime Temperature:

- **Impervious Surfaces**: A 10% increase in impervious surfaces (e.g., asphalt, concrete) raises the air temperature at 2 a.m. by approximately 0.97°C.
- **Tree Canopy:** A 10% increase in tree canopy coverage results in a cooling effect of around 0.33°C (Coseo & Larsen, 2014).

Consequences:

- **Health Risks:** The intensified UHI effect increases the risk of heat-related health issues, such as heat exhaustion and heatstroke. Particularly affects vulnerable populations: elderly, children, and individuals with pre-existing health conditions.
- **Energy Consumption:** Higher temperatures elevate the demand for cooling. Leads to increased electricity consumption and higher costs during peak periods.

Objective: Integrated analysis of seasonal temperature trends and heat risk in Chicago

- Uses climate station data from Midway (MDW) and Aurora(ARR) for urban low temperature comparative analysis
- Incorporates spatial information on land cover, population density, and maximum temperatures for an Urban Canopy index
- Pinpointing areas of socioeconomic vulnerability within the city
- Aims to develop a Heat Risk Index (HRI) and Heat Index Map for urban resilience.

Methodology

Urban Canopy Analysis:

- Obtained spatial data from Multispectral Landsat and European Space Agency World Cover for land cover analysis.
- Processed land cover data to differentiate areas with substantial tree cover and area in need of more green spaces.
- Calculated tree cover and green space percentages using Zonal Statistics to evaluate and compare green infrastructure.

Socioeconomic Vulnerability Index:

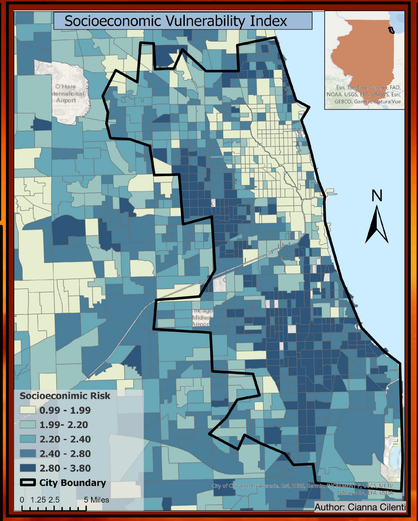
- Involved overlaying specific heat vulnerability indicators from the American Community Survey (ACS) to map areas at higher risk solely due to socioeconomic factors, informing targeted interventions to mitigate urban heat island effects
- Based on Nelson et al. (2011), which identified age and sex as key factors in susceptibility to heat-related illnesses, the index weighted datasets to find areas with the most at-risk populations. The datasets included age, sex, disability, household income, uninsured population, and population density.

Heat Risk Index (HRI) Calculation:

- Integrated population density, maximum temperature values, tree cover percentages, and socioeconomic factors.
- Developed a Heat Risk Index (HRI) to assess heat vulnerability across the city and displayed HRI results on a map to identify the heat risk areas.

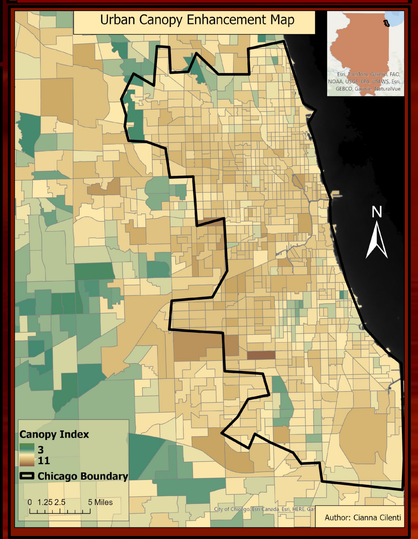
Seasonal Linear Regression and Anomaly Plots:

- Obtained Midway (MDW) and Aurora (ARR) airport climate data over a 30 year period (1991-2020) on low ambient temperature and feels-like.
- Performed linear regression to analyze trends and visualize anomalies in summer daily minimum temperatures and feels-like temperatures over the 30-year period. This statistical method helps to quantify how temperatures have changed over time, indicating whether there is a significant warming or cooling trend in each location.



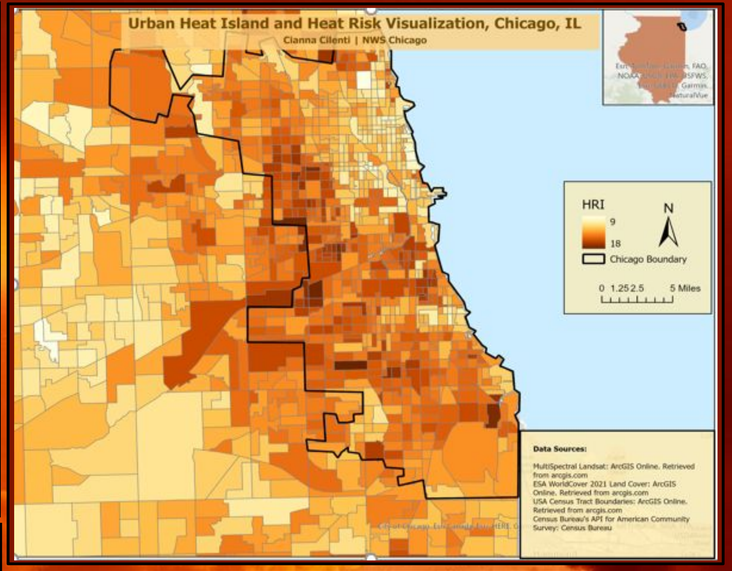
The south and west sides of Chicago face higher risks due to low income, limited healthcare, and high population density.

- Vulnerability scores in the high 2s and 3s reflect greater challenges.
- Uninsured rates reach 42%, with disability rates up to 40%.
- Seniors, children, and males (11% higher risk) face increased heat-related health risks.
- North side and suburban areas have lower risks, with higher incomes and fewer vulnerabilities.



The urban canopy enhancement map shows green space coverage with an index ranging from 3 (sufficient) to 11 (needs improvement).

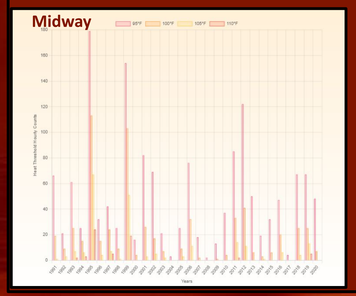
- Population densities in Chicago range from 3,000 to 77,000 people per square mile.
- Urban canopy coverage varies from 40% to less than 1%.
- Central and southwestern areas need more green spaces, while suburban and north/south areas have adequate coverage.

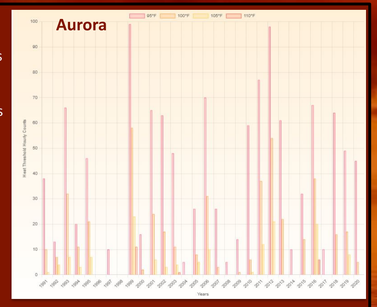


The Heat Risk Visualization map combines urban canopy coverage and socioeconomic risk to assess overall heat vulnerability. It shows a shift from the central and northwest parts of the city, which initially needed more green spaces, to the western-central and southern areas with higher scores due to socioeconomic factors.

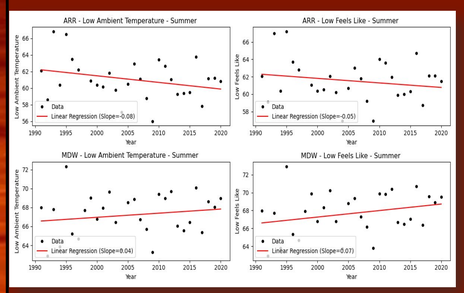
- Areas with scores upwards of 18 are at highest risk, lacking adequate green spaces and having socio-economically vulnerable populations. Outside city boundaries, scores drop to the 9-11 range, indicating less UHI effect and more dispersed populations.

The histogram for Midway illustrates the count of heat index exceedance hours during the months of July and August from 1991 to 2020. Peaks in extreme heat hours are noticeable in the early 1990s and again in the 2010s, with the highest values exceeding 160 hours for 95°F thresholds. This data emphasizes recurring periods of heightened summer heat risk in these months.





Aurora's data showcase the heat index exceedance hours during July and August from 1991 to 2020. While 95°F remains the most frequently surpassed threshold, the peak does not exceed 100 hours. Compared to Midway, Aurora exhibits fewer extreme heat hours, reflecting localized differences in summer heat exposure and risk.



Aurora (ARR) (Suburban Area):
Low ambient temperatures show a slight decrease over 30 years with a slope of -0.08, indicating cooler low "Feels like" temperatures also decline slightly (-0.05), but less notably than ambient lows, reflecting minimal suburban warming.

Midway (MDW) (Urban Area):
Low ambient temperatures display a rising trend with a slope of 0.04, while "feels like" temperatures increase more significantly (0.07). This highlights urban warming, with MDW showing a stronger urban heat island effect compared to ARR's suburban environment.

Conclusions

Identification of High-Risk Areas:

- Various indices identified high-risk areas in the city most susceptible to heat-related impacts.
- The urban canopy enhancement map highlighted north and central parts of the city with insufficient tree cover as particularly vulnerable.
- Socioeconomic vulnerability mapping revealed higher heat-related health risks in southern and central-western areas.
- Combining these indices into a heat index visualization pinpointed the southern and western regions as high-risk areas, where both socioeconomic factors and limited green space contribute to elevated heat risks.

- Trend Data:

- **Urban Heat Exceedance**: Urban areas like MDW experience higher heat index exceedances, surpassing 95°F and 100°F, due to the intensified Urban Heat Island (UHI) effect.
- **Nighttime Heat Stress**: Rising nighttime low temperatures in cities limit cooling and recovery, amplifying heat stress for residents.
- **Suburban Areas**: Suburban areas like ARR experience fewer heat index exceedances and cooler nighttime temperatures, thanks to reduced UHI effects and more vegetation.
- **Need for Interventions**: These differences emphasize the need for urban cooling strategies and green space expansion in high-risk urban areas to mitigate heat impacts.

Role of Urban Greenery: Areas with insufficient tree cover are particularly vulnerable to heat effects, indicating the critical role of urban greenery in mitigating heat risks.

Need for Targeted Interventions: Targeted interventions, like increased tree planting in high-risk areas, are essential to reduce heat-related health risks and boost urban resilience. Focusing on areas with limited green space and high socioeconomic vulnerability can significantly enhance the city's ability to manage extreme heat.

Implications:

- The results support the prediction that areas with less green space and lower socioeconomic status face higher heat-related health risks due to the intensified Urban Heat Island (UHI) effect.
- Findings highlight the need to enhance green infrastructure to manage rising temperatures and improve recovery times.
- Urban areas with warming lows experience less relief from the UHI effect, underscoring the need for effective cooling strategies and strategic urban planning.

Future Research

Quantitative Assessments: Conduct assessments to measure the impact of tree planting on local Chicago microclimates/ This can include evaluation of changes in air quality, energy consumption, and temperature changes.

Time-Line Analysis: Integrate future climate projections into the assessments of green infrastructure effectiveness. Integrates anticipated climate changes (e.g., increasing temperatures, precipitation patterns) and their influence on resilience and adaptive capacity of urban green spaces.

Comparative Analysis: Compare the various types of green infrastructure to identify the most effective strategies for heat resilience under various climatic conditions and urban contexts.

References and Acknowledgements

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For additional climate and lake data for the Chicago area, along with biography and contact information please scan the above QR Code.