Mapping Social and Environmental Health Vulnerability in Madison, New Jersey

Elias Chang, Rai Chowdhury, Zihan Chu, Shiven Das, Ethan Dougherty, Avaneesh Gore, Brianna Jimenez, Luke Nathan, David Pevzner, Evie Shen, Mia Teng

Advisor: Han Yan, Ph.D.
Assistant: Sofia D'Amelio

What is GIS?

- Geographic Information Systems
  - Technology using geospatial data to analyze and identify patterns across different locations
  - Consists of secondary data from credible sources
  - Firsthand data can also be collected and converted for deeper spatial analysis to create connections

Introduction

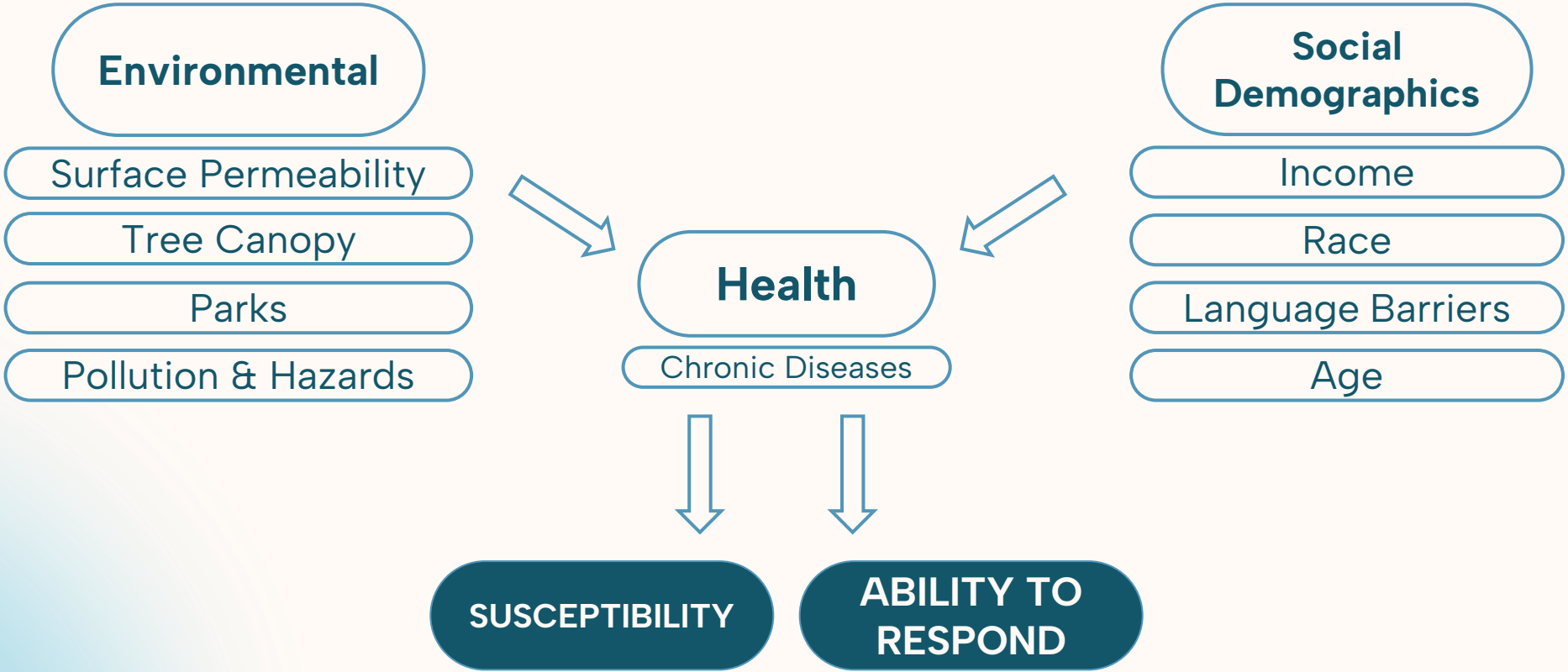
- For every *1.8 ºF increase*, heat illness morbidity/mortality rates increase by *18%* (Faurie et al., 2022).

SES Status → Environment → Heat Illness Risk → Health Status

Social Vulnerability: Capacity for communities to recover from stressors.

Heat Vulnerability: Susceptibility of individuals to heat-related issues.

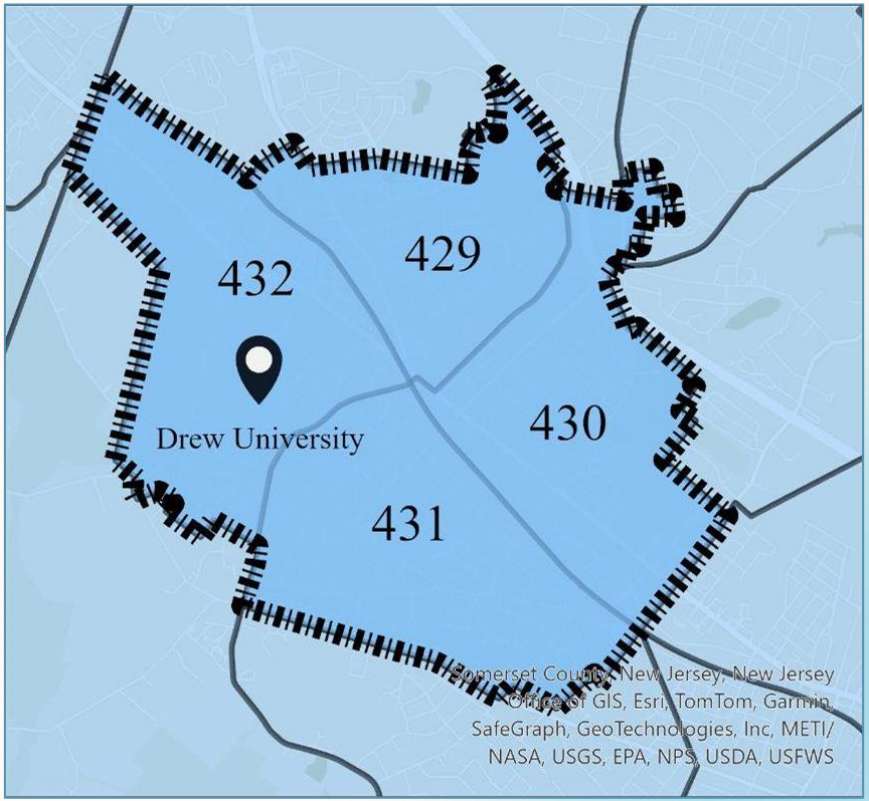
Connecting Social, Environmental, and Health Factors



Research Question:

To what extent are social demographic and environmental factors (tree canopies and impervious surfaces) associated with the public health risks for residents in Madison, New Jersey?

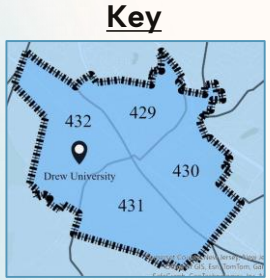
Study Area

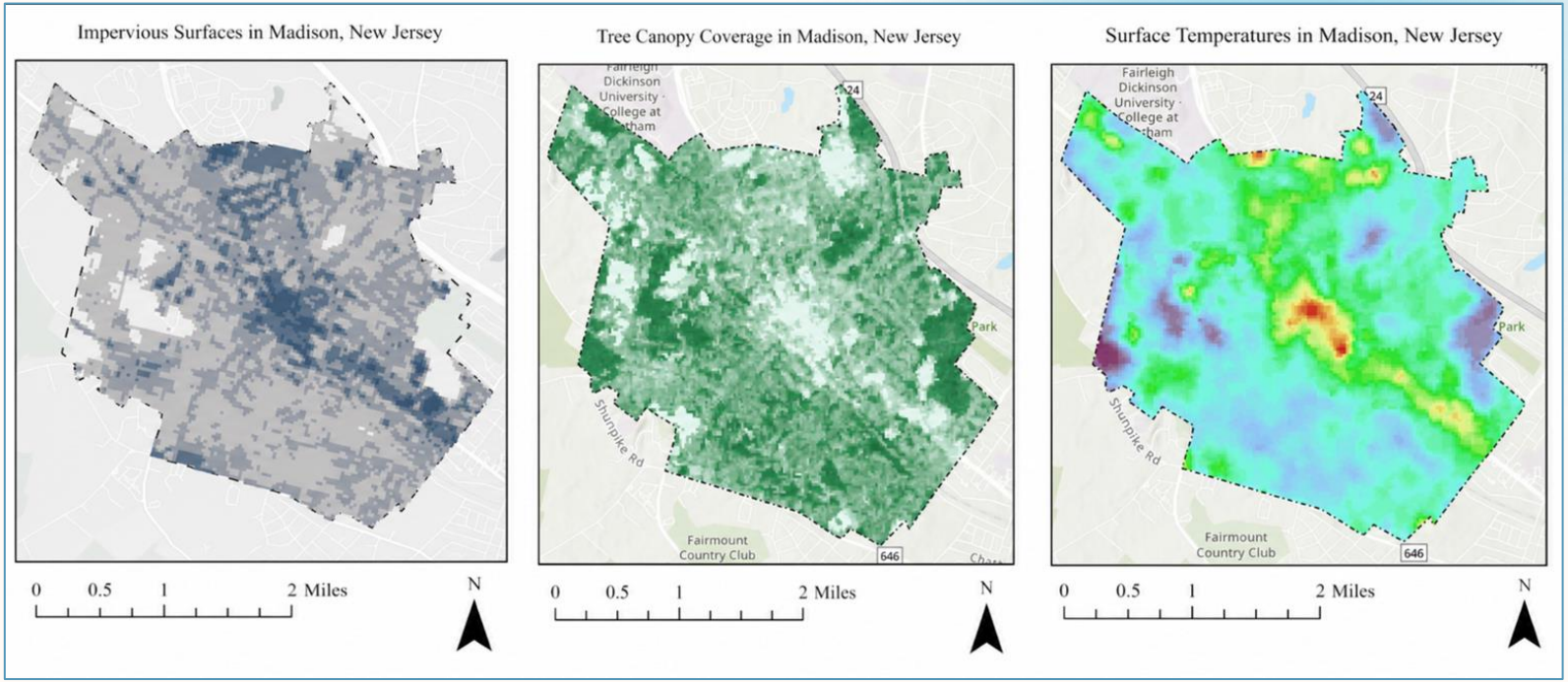

432
429
430
431
Drew University
Somerset County, New Jersey, New Jersey Office of GIS, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/ NASA, USGS, EPA, NPS, USDA, USFWS

Methodology

- Geospatial Data Investigation
- Nested Scale Temperature Investigation
- Vulnerability Multicriteria Analysis

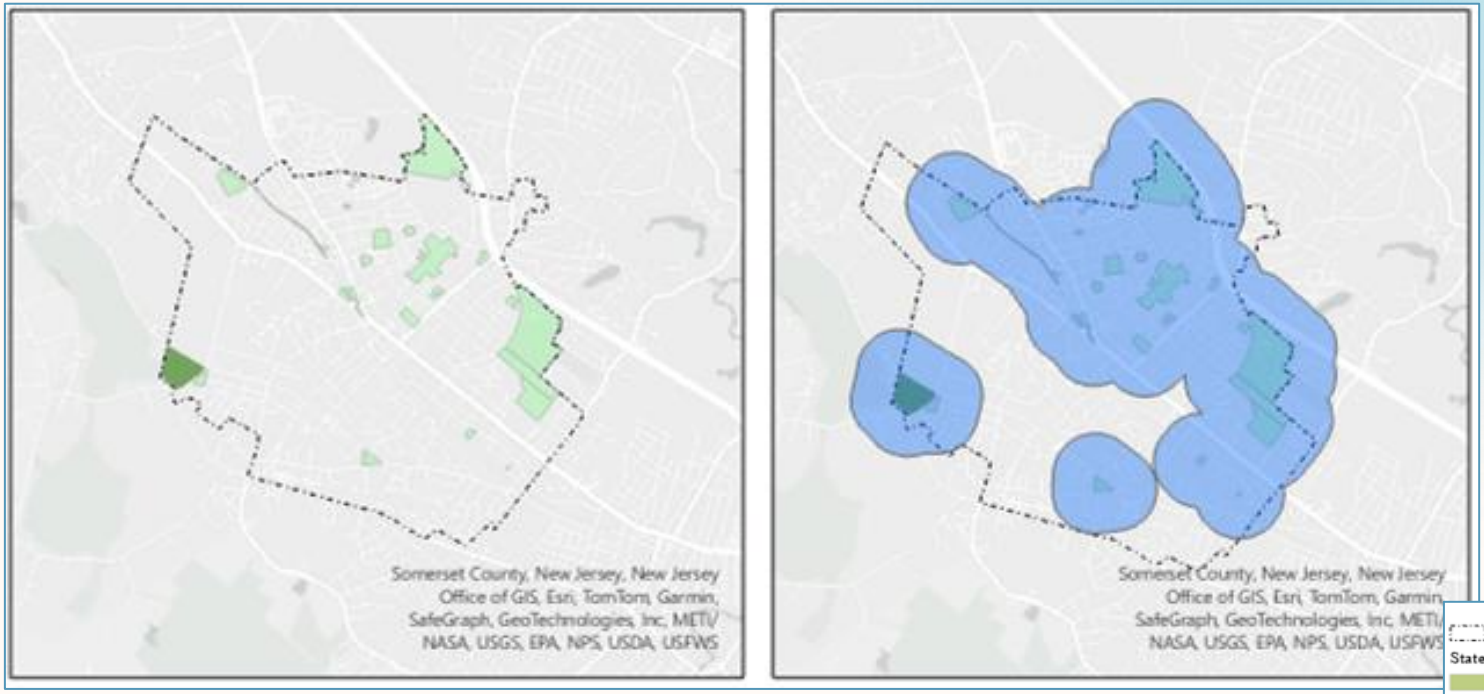
Results: Environmental Investigation



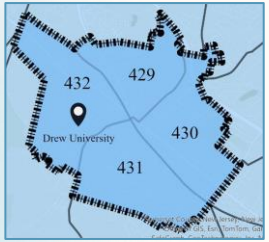


Layer Sources: NLCD (2026). USDA Forest Service (2025). NJDEP Bureau of GIS (2023).

Results: Open Space Investigation



Key

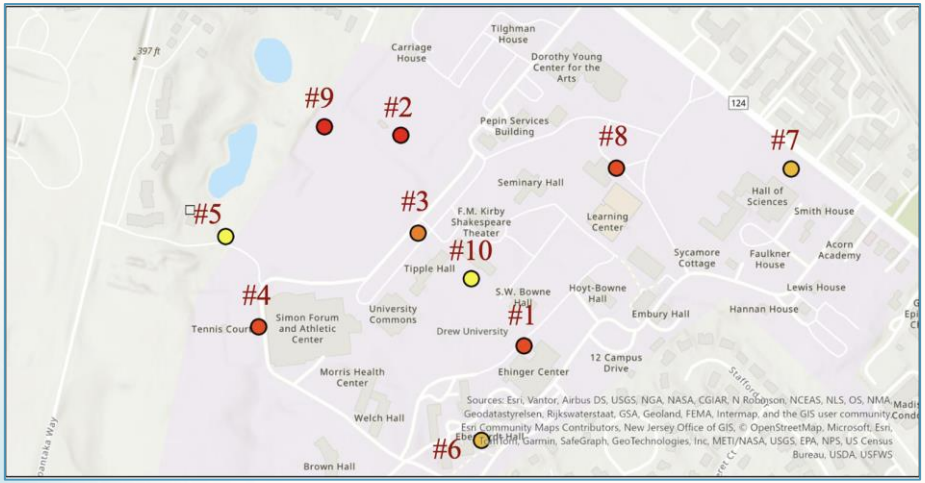


Municipal Boundaries of NJ, Hosted, 3857
State, Local and Nonprofit Open Space of New Jersey
Federal (State Owned)
Federal (State Owned)
Fish and Wildlife
Parks and Forestry
Natural Lands Trust
County
County
County (Not Encumbered)

Layer Sources: NJDEP Bureau of GIS (2026).

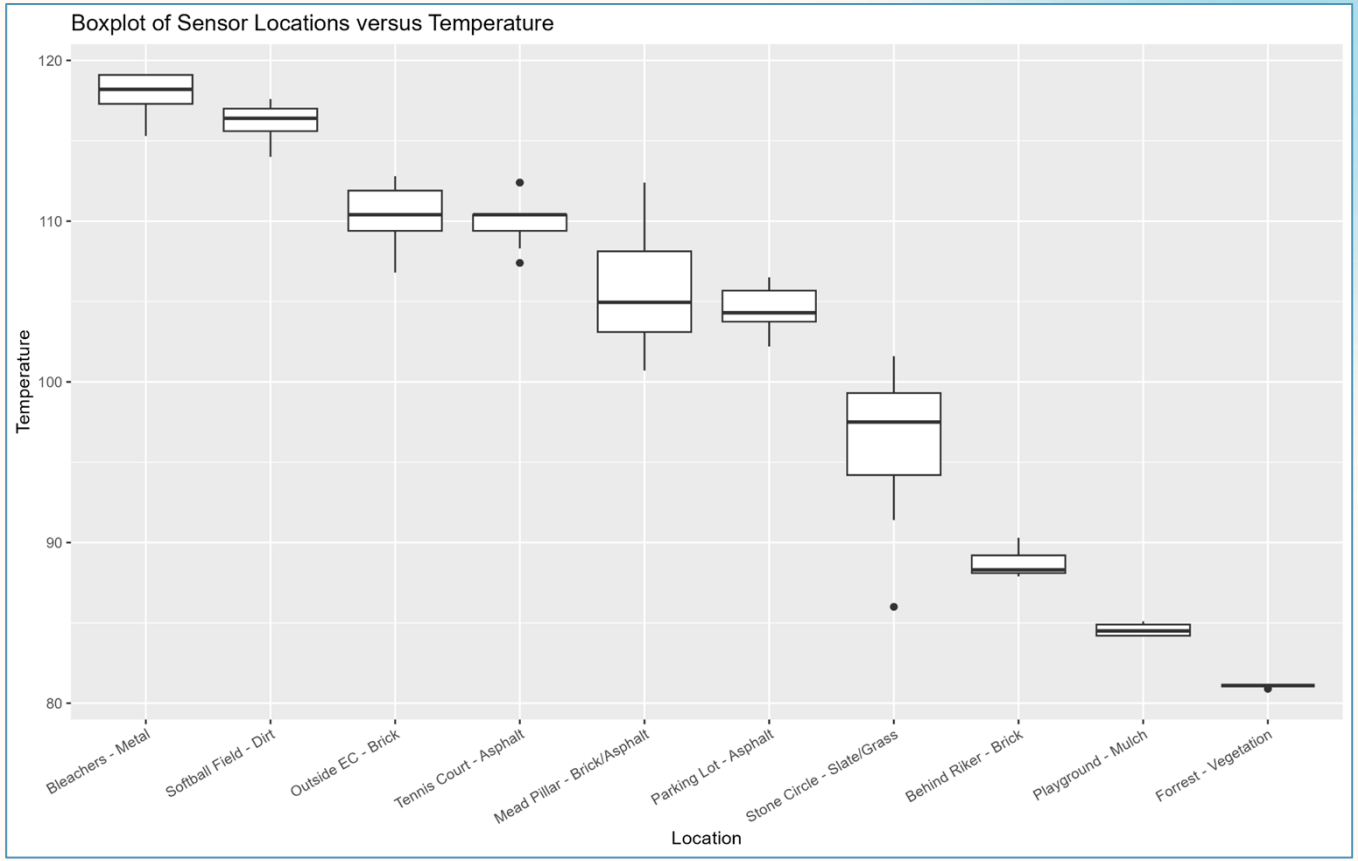
Methodology: Nested Scale Temperature Investigation

Site Number	1	2	3	4	5	6	7	8	9	10
Surface Material Type	Brick	Metal	Asphalt	Asphalt	Vegetation	Brick	Slate & Grass	Brick & asphalt	Dirt	Mulch



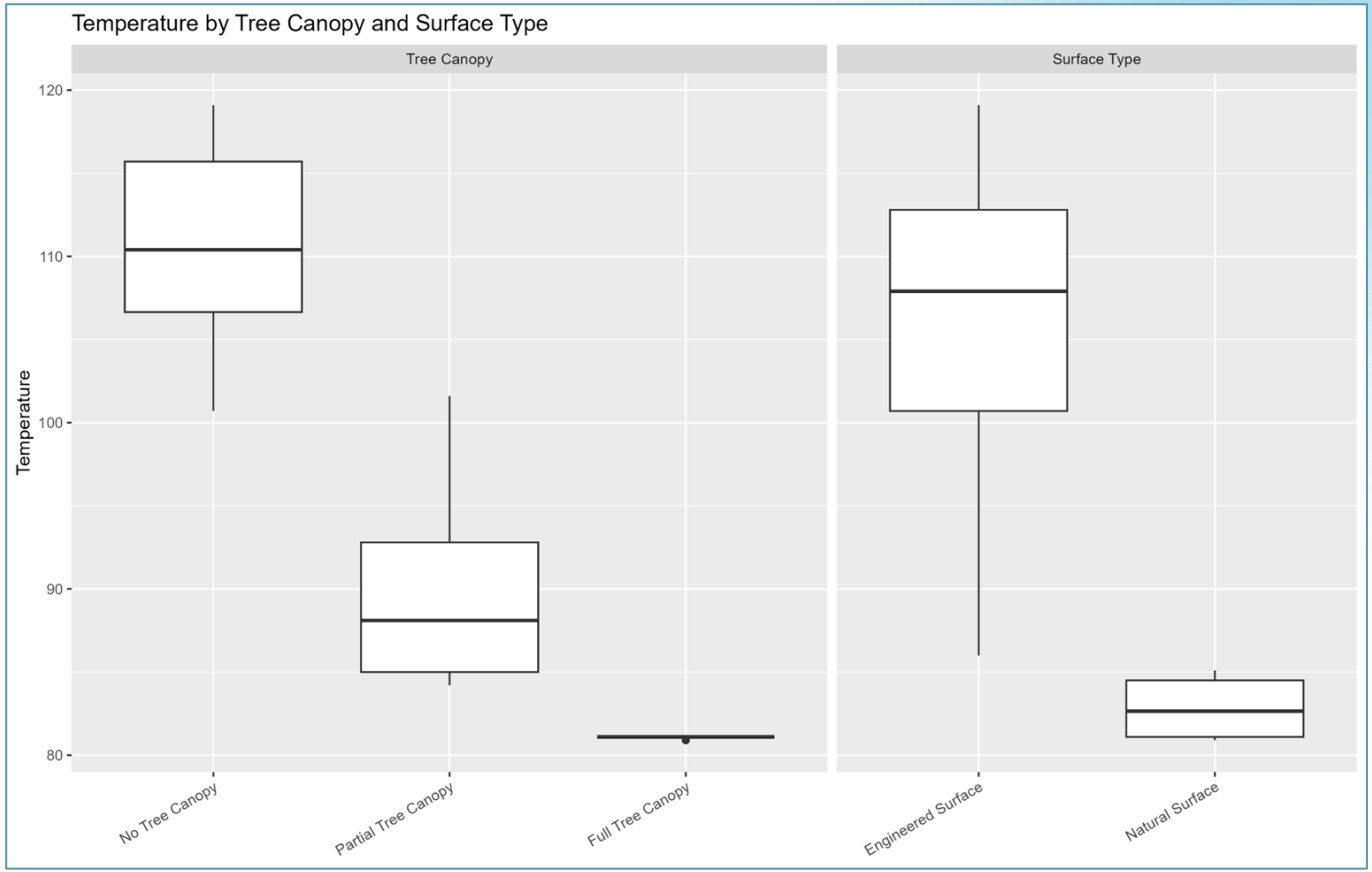
- Taking survey and temperature data using Freshliance sensors
- Drew University campus
- 10 sites
- Temperature collected 2:58-3:40pm
- Data Analysis: one-way ANOVA test in R Studio

Results: Nested Scale Temperature Investigation



- Metal Bleachers (117.8 ºF)
- Forest Vegetation (81.1 ºF)
- One-way ANOVA p-value (2.24e-55)

Results: Nested Scale Temperature Investigation

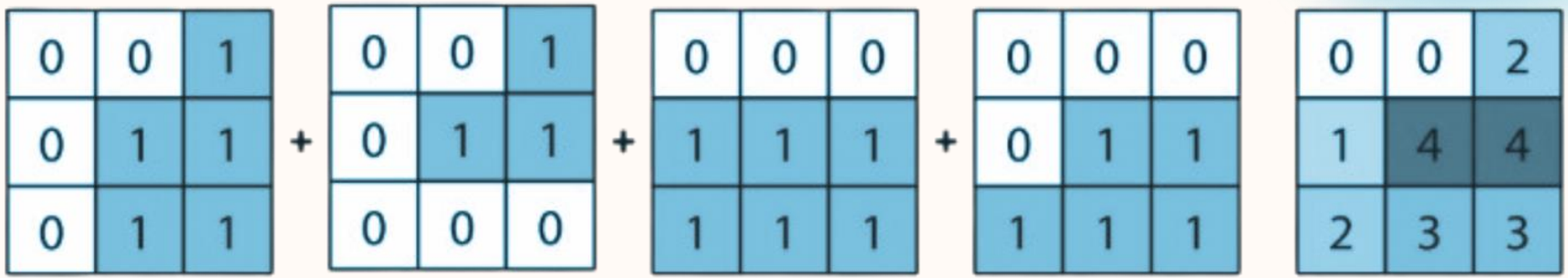


- No Tree Canopy (110.9 °F)
- Partial Tree Canopy (89.8 °F)
- Full Tree Canopy (81.1 °F)
- One-way ANOVA p-value (2.29e-34)

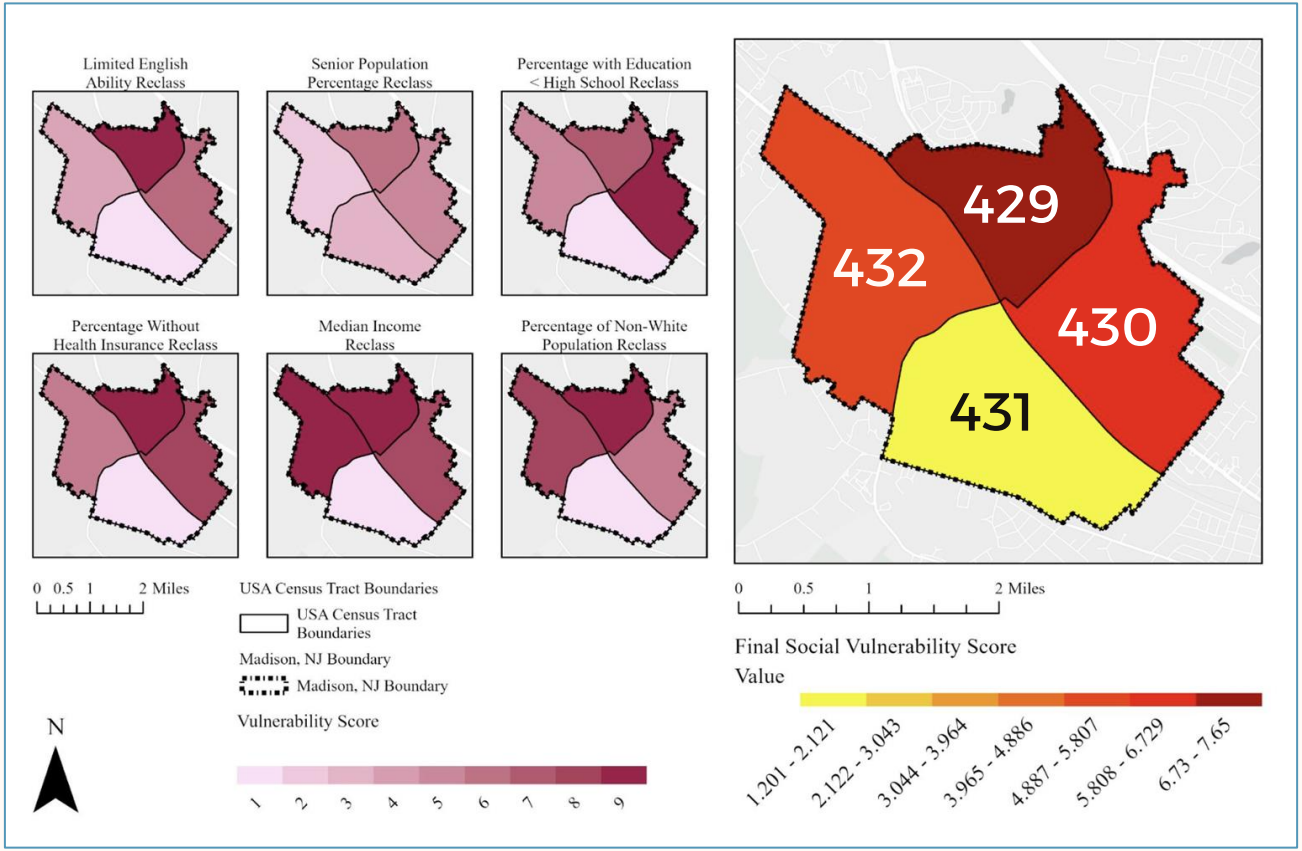
- Engineered Surfaces (106.1 °F)
- Natural Surfaces (82.8 °F)
- One-way ANOVA p-value (2.08e-10)

Multicriteria Vulnerability Analysis

$$\text{Final Social Vulnerability Score} = 0.20(\text{Median Income Reclass}) + 0.20(\text{Senior Population Percentage Reclass}) + 0.15(\text{Education Less Than High School}) + 0.15(\text{Limited English Ability Reclass}) + 0.15(\text{Without Health Insurance}) + 0.15(\text{Percentage Non-White})$$

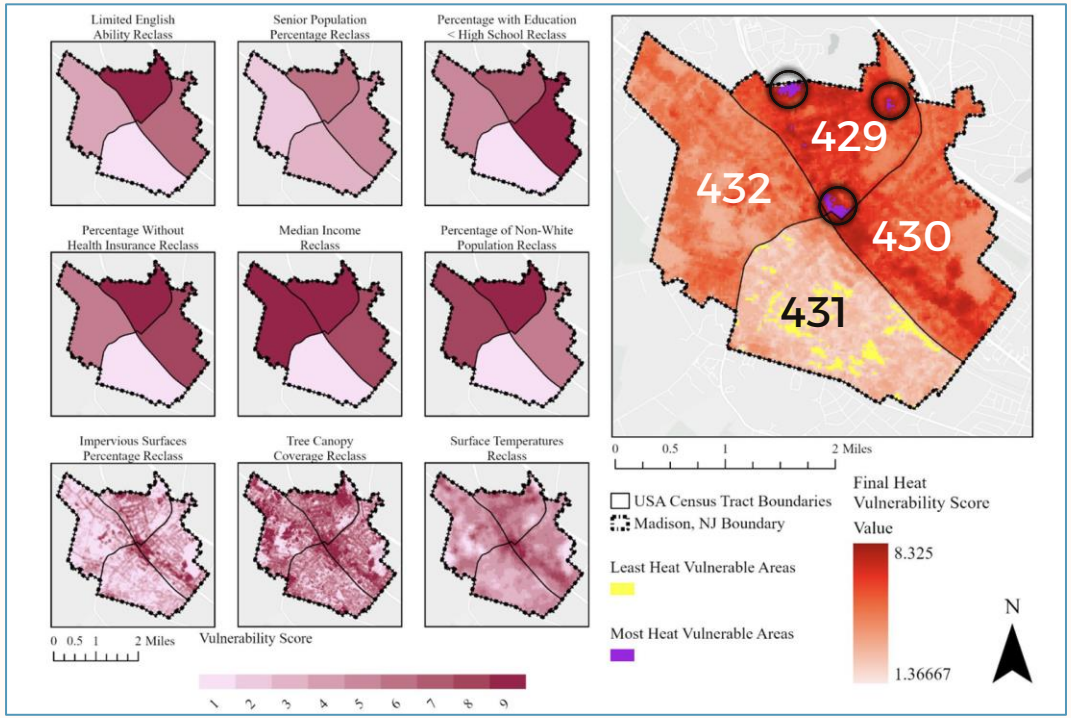


Highest Social Vulnerability: Tract 429



Layer Sources: ACS (2025). ACS (2026). Esri (2026). CDC PLACES (2026).

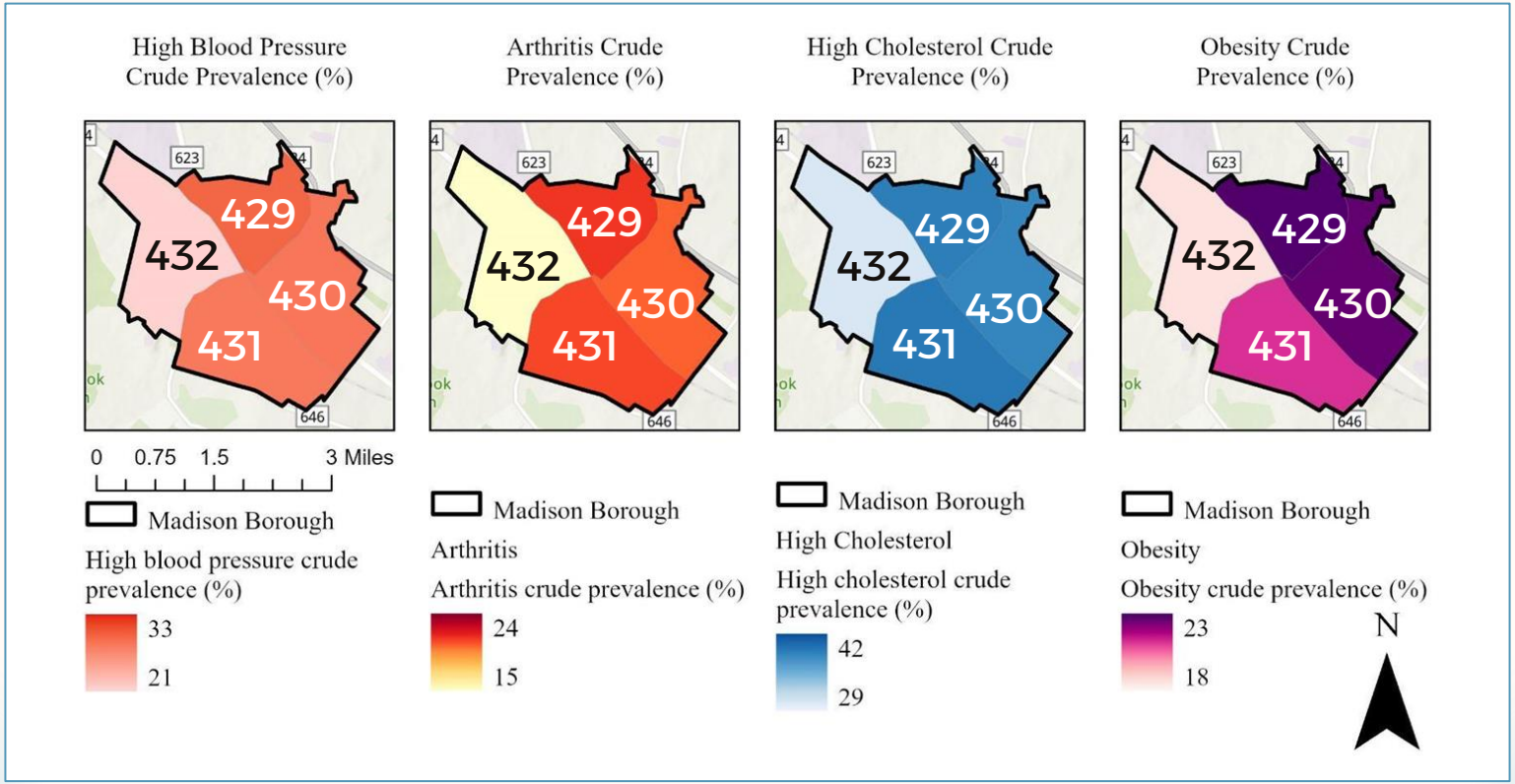
Heat Vulnerability in Madison, New Jersey



$$\text{Final Heat Vulnerability Score} = 0.167(\text{Impervious Surfaces Reclass}) + 0.167(\text{Tree Canopy Coverage Reclass}) + 0.167(\text{Surface Temperatures Reclass}) + 0.10(\text{Median Income Reclass}) + 0.10(\text{Senior Population Percentage Reclass}) + 0.075(\text{Education Less Than High School}) + 0.075(\text{Limited English Ability Reclass}) + 0.075(\text{Without Health Insurance}) + 0.075(\text{Percentage Non-White Population})$$

Layer Sources: ACS (2025). ACS (2026). Esri (2026). CDC PLACES (2026). USDA Forest Service (2025). NJDEP Bureau of GIS (2023).

Results: Health Investigation



Layer Sources: CDC Places (2026).

Summary

The spatial patterns suggest a greater concentration of social and heat vulnerability, and health-related risk factors in Census Tract 429.

Limitations

- We only considered social demographic factors at the level of census tracts but not further
- Age-related data may be skewed by the two private universities in the borough of Madison
- The study identifies spatial patterns, but is unable to assign a causal relationship to these patterns

Future Applications

Census Tract 429

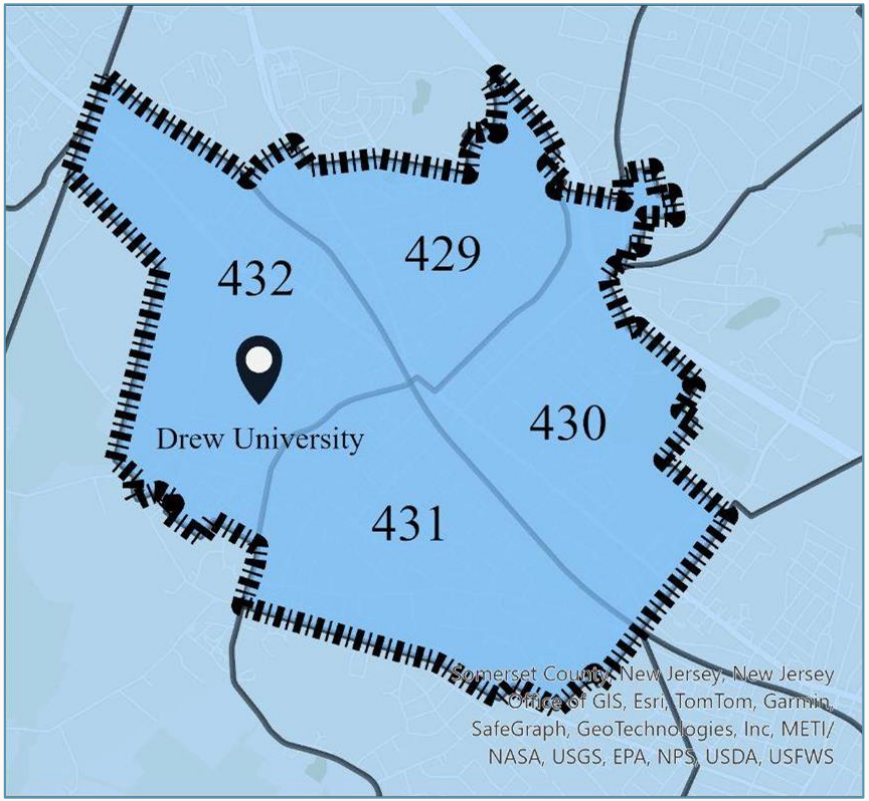
- Professional development
- Green space
- Health accessibility

Census Tract 430

- Walkable infrastructure + accessible recreation spaces/fitness programs

Census Tract 431

- Nutrition assessment/awareness



References

Centers for Disease Control and Prevention. 2024. Social Vulnerability Index. Available from: https://www.atsdr.cdc.gov/place-health/php/svi/index.html

Centers for Disease Control and Prevention. 2026. About chronic diseases. Available from: https://www.cdc.gov/chronic-disease/about/index.html

Chen AM. 2025. Barriers to health equity in the United States of America: can they be overcome? *International Journal for Equity in Health*. *24*(1):39. doi:10.1186/s12939-025-02401-w

Couillard BK, Foote CL, Gandhi K, Meara E, Skinner J. 2021. Rising geographic disparities in US mortality. *The Journal of Economic Perspectives*. *35*(4):123–146. doi:10.1257/jep.35.4.123

Ewert A, Chang Y. 2018. Levels of nature and stress response. *Behavioral Sciences*. *8*(5):49. doi:10.3390/bs8050049

Faurie C, Varghese BM, Liu J, Bi P. 2022. Association between high temperature and heatwaves with heat-related illnesses: A systematic review and meta-analysis. *The Science of the Total Environment*. *852*:158332. doi:10.1016/j.scitotenv.2022.158332

Hajat A, Hsia C, O'Neill MS. 2015. Socioeconomic Disparities and Air Pollution Exposure: a Global Review. *Current Environmental Health Reports*. *2*(4):440–450. doi:10.1007/s40572-015-0069-5

Lindsey R, Dahlman L. 2025. *Climate change: Global temperature*. NOAA Climate.gov. Available from: https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Macias-Konstantopoulos WL, Collins KA, Diaz R, Duber HC, Edwards CD, Hsu AP, Ranney ML, Riviello RJ, Wettstein ZS, Sachs CJ. 2023. Race, Healthcare, and Health Disparities: A Critical Review and Recommendations for Advancing Health Equity. *Western Journal of Emergency Medicine*. *24*(5):906–918. doi:10.5811/westjem.58408

McDonald RI, Kroeger T, Zhang P, Hamel P. 2019. The value of US urban tree cover for reducing Heat-Related health impacts and electricity consumption. *Ecosystems*. *23*(1):137–150. doi:10.1007/s10021-019-00395-5

Nanda L, Chakraborty S, Mishra SK, Dutta A, Rathi SK. 2022. Characteristics of Households' Vulnerability to Extreme Heat: An Analytical Cross-Sectional Study from India. *International Journal of Environmental Research and Public Health*. *19*(22):15334. doi:10.3390/ijerph192215334

Nazish A, Abbas K, Sattar E. 2024. Health impact of urban green spaces: a systematic review of heat-related morbidity and mortality. *BMJ Open*. *14*(9):e081632. doi:10.1136/bmjopen-2023-081632

Niccoli T, Partridge L. 2012. Ageing as a risk factor for disease. *Current Biology*. *22*(17):R741–R752. doi:10.1016/j.cub.2012.07.024

Pandey M, Maina RG, Amoyaw J, Li Y, Kamrul R, Michaels CR, Maroof R. 2021. Impacts of English language proficiency on healthcare access, use, and outcomes among immigrants: a qualitative study. *BMC Health Services Research*. *21*(1):741. doi:10.1186/s12913-021-06750-4

Park S, Fung V. 2025. Health care affordability problems by income level and subsidy eligibility in Medicare. *JAMA Network Open*. *8*(9):e2532862. doi:10.1001/jamanetworkopen.2025.32862

Peitzman C, Tartak JAC, Samuels-Kalow M, Raja A, Macias-Konstantopoulos WL. 2023. Racial Differences in Triage for Emergency Department Patients with Subjective Chief Complaints. *Western Journal of Emergency Medicine*. *24*(5):888–893. doi:10.5811/westjem.59044

United States Census Bureau. 2025. *QuickFacts: Madison borough, New Jersey*. United States Census Bureau. Available from: https://www.census.gov/quickfacts/fact/table/madisonboroughnewjersey/pst045225

United States Environmental Protection Agency. 2024. What are heat islands? Available from: https://www.epa.gov/heatislands/what-are-heat-islands

Weighted Sum (Spatial Analyst Tools) | ArcGIS Pro documentation. 2026. Esricom. [accessed 2026 July 30]. https://doc.esri.com/en/arcgis-pro/latest/tool-reference/spatial-analyst/weighted-sum.html?tabs=dialog.

Wolch J, Jerrett M, Reynolds K, McConnell R, Chang R, Dahmann N, Brady K, Gilliland F, Su JG, Berhane K. 2010. Childhood obesity and proximity to urban parks and recreational resources: A longitudinal cohort study. *Health & Place*. *17*(1):207–214. doi:10.1016/j.healthplace.2010.10.001

World Health Organization. 2026. *Heat and health*. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health

Zafra M. 2025. How concrete, asphalt and urban heat islands add to the misery of heat waves. *Reuters*. Available from: https://www.reuters.com/graphics/CLIMATE-CHANGE/URBAN-HEAT/byvrejywdpe/

A special thank you

Advisor: Han Yan, Ph.D.
Assistant: Sofia D'Amelio

Representatives of

THE BOROUGH OF
MADISON
NEW JERSEY

Governor's School of New Jersey, Program in the Sciences is possible because of:

Office of the Secretary of Higher Education (OSHE) of New Jersey
Overdeck Family Foundation
Garden State Initiative
Novartis
Bristol Myers Squibb
BASF
New Jersey Governor's School of the Sciences Alumni & Parents of Alumni