HEAT WAVES

Designing a Heat Action Plan to Mitigate Disproportionate Impacts of Urban Heat Island Effect in Underserved Communities in Omaha, NE

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1. EXECUTIVE SUMMARY

Abstract

This study builds on a transdisciplinary collaboration between the City of Omaha, University of Nebraska Medical Center, University of Nebraska - Lincoln College of Architecture, and Community-based Organizations to develop a Heat Action Plan to mitigate the disproportionate impacts of urban heat island effect in underserved communities in Omaha, NE.

Research Problem Statement

Extreme heat kills more people in the United States than any other natural disaster. These effects are more pronounced in urban environments, where buildings, roads, and other infrastructure absorb and re-emit the sun's heat, otherwise known as urban heat island effect. The increasing intensity, duration, and frequency of heat waves disproportionately impact underserved populations in a heightened state of precarity. There is a significant gap in the research on applied approaches to integrating mitigation and adaptation strategies for addressing extreme heat, particularly in underserved communities. Omaha, NE, a 'hypersegregated' city, would benefit from a transdisciplinary Heat Action Plan.

First Quarterly Task

In the first quarter, the research team focused on gathering resources to assist in the development of a heat action plan as well as produce a booklet of relevant heat mitigation and adaptation strategies.

2. INTRODUCTION

Urban heat resilience is a growing issue as extreme heat kills more people in the United States than any other natural disaster (Berko, 2014). The earth consistently faces increased heat waves, in which 15 of the 16 warmest years on record have occurred during this century. This year, 2022, is expected to rank among the 10 hottest years in annual global temperature readings (NOAA, 2022). Rising temperatures contribute to the intensification of environmental threats, such as drought and rising sea levels. Higher average temperatures also raise health risks by leading to increased energy use and subsequently pollution. According to the Intergovernmental Panel on Climate Change (IPCC), we face longer continuous stretches of higher temperatures that pose greater health risks than isolated extreme heat events. Heat-related illnesses, such as heat stress, asthma, and malaria, are expected to claim an additional 250,000 lives between 2030 and 2050 (Neira, 2016). These effects are more pronounced in urban environments, where buildings, roads, and other infrastructure absorb and re-emit the sun's heat—a phenomenon known as urban heat island effect (EPA, 2022).

Today, researchers think of the heat island as more of an archipelago, where hot spots are heterogeneously distributed throughout a city in locations with higher concentrations of concrete and asphalt, whereas cooler temperatures can be found around trees, parks, or other open space (Borunda, 2021). The increasing intensity, duration, and frequency of heat waves have been found to disproportionately impact underserved populations in a heightened state of precarity. In a study of 108 urban areas nationwide, the formerly redlined neighborhoods of nearly every city studied were hotter than the non-redlined neighborhoods, some by nearly 13 degrees Fahrenheit (Hoffman, 2020). Redlining is the historical discriminatory practice of refusing home loans or insurance to whole neighborhoods based on a racially-motivated perception of safety for investment.

Omaha, NE is one such example of a city that suffers from the lingering impacts of redlining, consistently rated among the top 50 most segregated cities in the US (UC Berkeley, 2020). The Omaha metropolitan area has been categorized as a 'hypersegregated' city, which is a term used to describe metropolitan areas in which African Americans were highly segregated in at least four of five dimensions of segregation: unevenness, isolation, clustering, concentration, and centralization (Massey, 2015). An ongoing study of extreme heat in Omaha has found a 10 degree difference in historically redlined neighborhoods (Abdoulaye, 2022). Along with disproportionate heat intensity, redlined neighborhoods in Omaha are also faced with increased levels of lead and coal contamination. In 1999, the EPA found that residential yards in eastern Omaha, including the historically redlined and segregated Black community of North Omaha, had high concentrations of lead due to historic industrial air emissions; as a result, this area was designated as a Lead Superfund Site (EPA, 2017).

These environmental injustices have not gone without notice. The EPA has since remediated more than 13,000 residential properties at the superfund site between 1999 and 2015 (EPA, 2017) and recently, the City of Omaha has announced plans to develop a climate action plan to be completed by June 2024. According to Omaha Mayor, Jean Stothert, tackling extreme heat is among the goals of the plan. Heat action plans have been gaining traction as a process for identifying both mitigative and adaptive strategies for countering heat intensity, especially as a form of addressing environmental injustices (TNC, 2019)(Guardaro, 2020). Mitigating the inequitable distribution of intense surface temperatures requires a multifaceted approach incorporating policy, public health, urban planning, and landscape strategies. Designing resilient cities requires an understanding of how they can "persist, adapt, and transform in the face of stress, while maintaining their function and identity" (Meerow & Newell, 2016).

This study aims to build upon a collaborative partnership between the City of Omaha Planning Department, University of Nebraska Medical Center, and the University of Nebraska - Lincoln College of Architecture to develop a Heat Action Plan. There are a myriad of potential solutions to extreme heat, but there is no one-size-fits-all approach. It is crucial to recognize that impactful collaborations require the "collective capacity of academic, health, and environmental leaders, along with the communities themselves" to develop a coordinated plan that transcends silo-based actions and limited nature-based solutions (NbS) (Kabisch, 2016)(Guardaro, 2020).

Developing a Heat Action Plan through a participatory process will contribute to the development of mitigation and adaptation strategies that work for a particular context. Urban heat solutions generally fall into two categories, mitigation and adaptation (TNC, 2019). Mitigation involves reducing the heat of the urban environment through a variety of nature-based and architectural interventions, including increasing shade through tree planting, using high albedo surfaces, and reducing greenhouse gas emissions. Adaptation is the adjustment to environmental conditions by changing behavior to deal with the increased intensity of extreme heat. These can include strategies such as taking alternative forms of transportation, providing free public drinking water, and opening a cooling center. Equitable access to shade and sensible microclimates are often perceived as an amenity, but should be considered a public health concern (Bloch, 2019). As deadly heat waves become commonplace, we must consider it as a civic resource shared by all.

3. METHODS

3.1 Study area

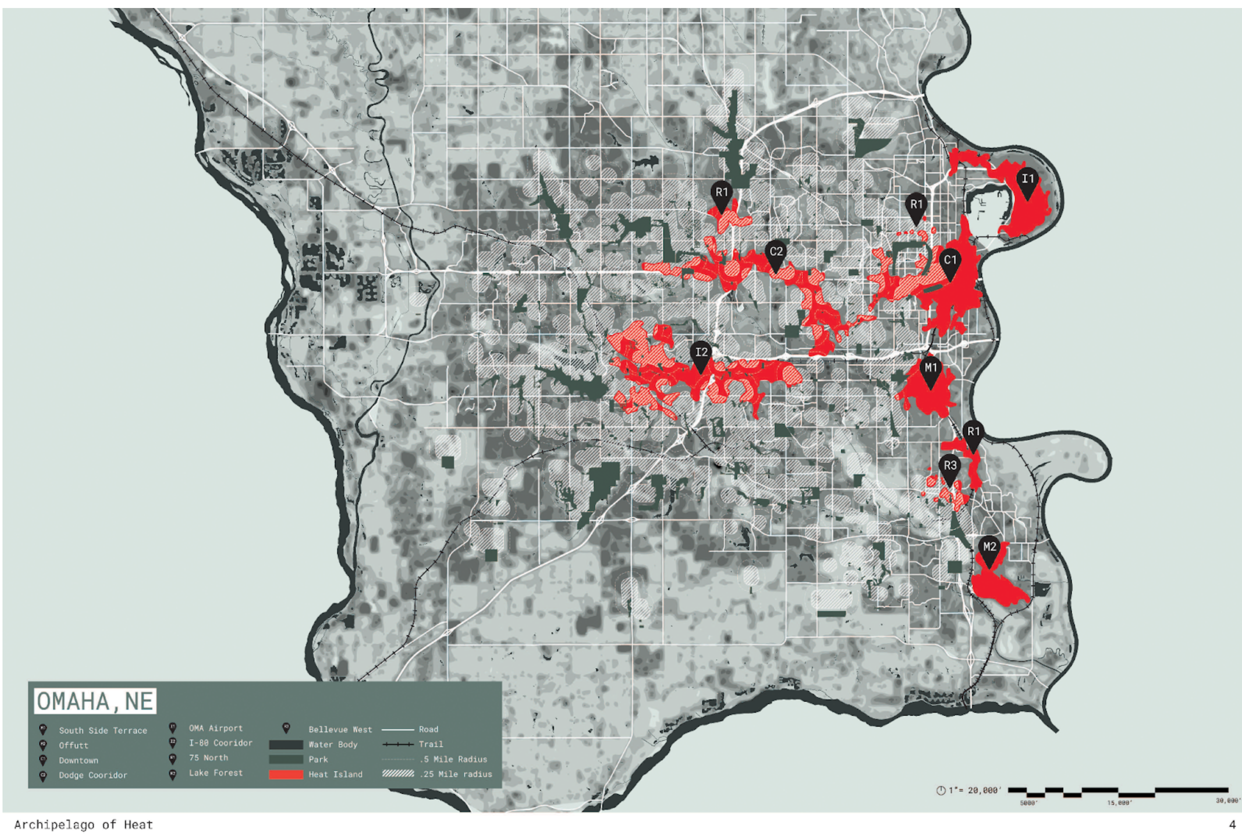

Figure 1. Sarpy and Douglas County area delineation with Landsat9 Land Surface Temperature data.

The study area includes Sarpy and Douglas County which encapsulates the municipal boundary of the City of Omaha (See Figure 1.). The Heat Action Plan focuses on the identification of the heat archipelago as a form of vulnerability assessment. Sarpy and Douglas County were used as a form of delineation due to readily available Geographic Information Systems (GIS) Data. The City of Omaha ranges in average high temperatures of 33°F (January) to 87°F (July)(See Figure 2.)(US Climate Data, 2023).

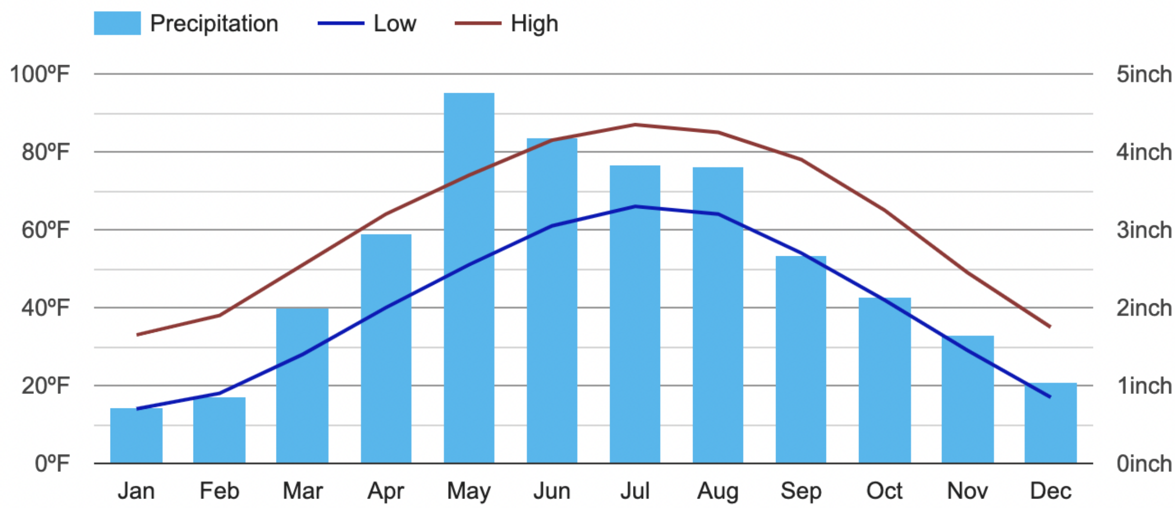

Figure 1. Omaha Climate Graph (US Climate Data, 2023).

3.2 Identifying Heat Resources

To guide the development of a heat action plan, the team began by compiling available resources and literature. It is not within the scope of this research to conduct a comprehensive literature review, although we found it necessary to develop a baseline understanding of available resources. A full list of references can be found at the end of this document. Two particular documents were referenced as primary sources to help guide this process: "Planning for Urban Heat Resilience" by Keith and Meerow, 2022 and "The Heat Action Platform" by the Adrienne Arsht-Rockefeller Foundation Resilience Center.

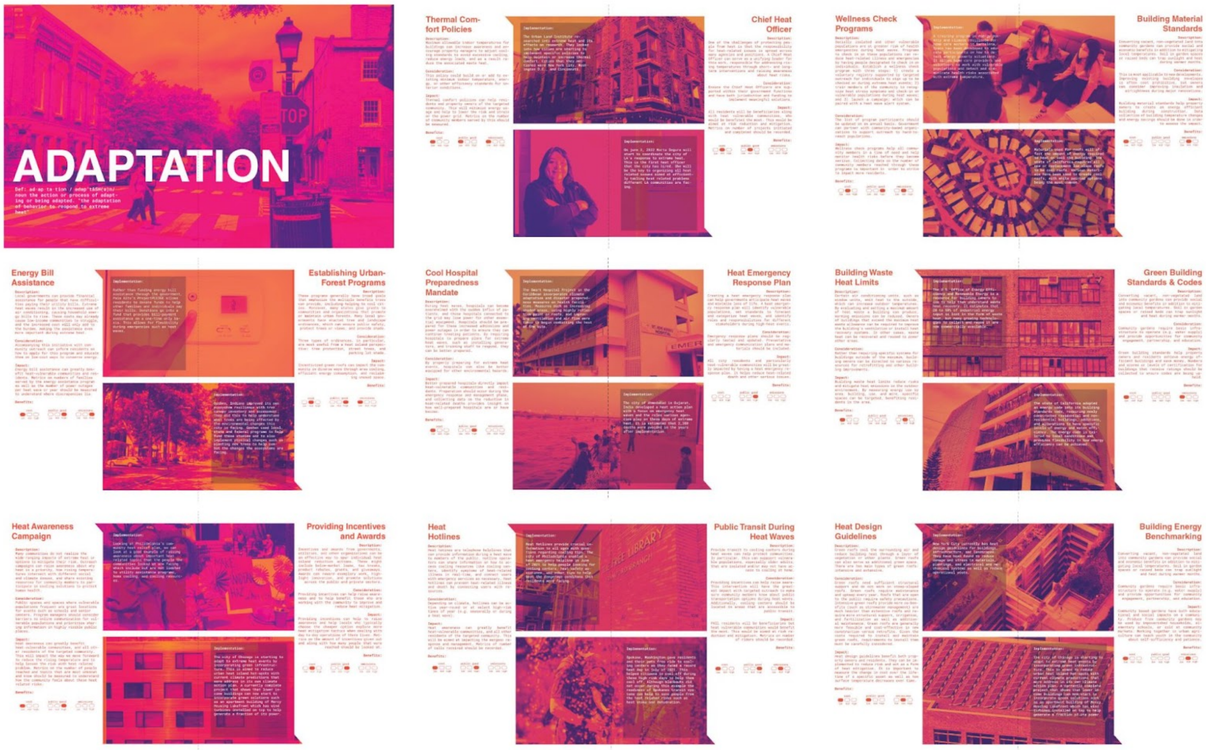

Figure 3. Adaptation Strategies.

By investigating these two resources, students in the third-year LARC 311 Design Studio IV: Ecological and Cultural Landscape Systems compiled strategies and case studies into a Thermal Tactics booklet (See Figure 3.). Additionally, the team conducted research into Heat Action Plan case studies, including: Greater Phoenix Heat Action Planning Guide (2019), Karachi Heat Action Plan (2017), Western Sydney Heat Action Plan (2018), and the Ahmedabad Heat Action Plan (2019). In the Greater Phoenix Heat Action Planning Guide, we found that urban heat solutions generally fall into two categories, mitigation and adaptation (TNC, 2019) (See Table 1.). Mitigation involves reducing the heat of the urban environment through a variety of nature-based and architectural interventions, including increasing shade through tree planting, using high albedo surfaces, and reducing greenhouse gas emissions. Adaptation is the adjustment to environmental conditions by changing behavior to deal with the increased intensity of extreme heat. These can include strategies such as taking alternative forms of transportation, providing free public drinking water, and opening a cooling center.

	Adaptation		Mitigation
Community	Energy bill assistance	Material	Permeable pavement
	Establishing urban forestry, tree, and landscape program		Public Shading Structures
	Heat awareness campaign		Heat resilient building materials
	Providing incentives and awards		Light pavement
	Thermal comfort policies	Architecture	Building orientation and massing
Emergency	Chief heat officers		Passage space under building
	Cool hospital preparedness mandate		Cool roofs / walls
	Heat emergency response plan		Exterior building shading
	Heat hotlines		Green building
	Public transit services during heat waves	Green Infrastructure	Tree protection
	Wellness check programs		Urban forests
Infrastructure	Building materials and standards		Open space
	Building waste heat limits		Water features
	Green building and energy efficiency standards and codes		Greenroofs
	Heat design guidelines		Community gardens
Assessment	Building energy benchmarking		Stormwater Retention
	Catastrophe (CAT) bond	Energy	Walkability
	Conduct a heat vulnerability assessment		Electric Vehicle Infrastructure
	Design a heat management plan		Waste heat reduction
	Heat-resilient environmental impact assessments		Microgrids

Table 1. Adaptation and Mitigation Strategies.

3.3 Mapping the Heat Archipelago

a. Landsat

To determine where both hot and cool islands occur, Landsat 9 satellite imagery was used. Imagery from August 3rd, 2022 over Omaha, Nebraska was collected from the USGS Earth Explorer website, with a focus on thermal bands 4,5, and 10 and the metadata contained within that Landsat data. Various calculations were performed using ArcGIS Pro to find the top of atmosphere (TOA), brightness temperature, normalized difference vegetation index (NDVI), vegetational cover, emissivity, and, ultimately, land surface temperature. The land surface temperature raster data was normalized to ten internals and then transformed into vector data for analysis. We located eight heat islands from the vector data which had four different predominant land uses: Commercial, Industrial, Mixed Use, and Residential.

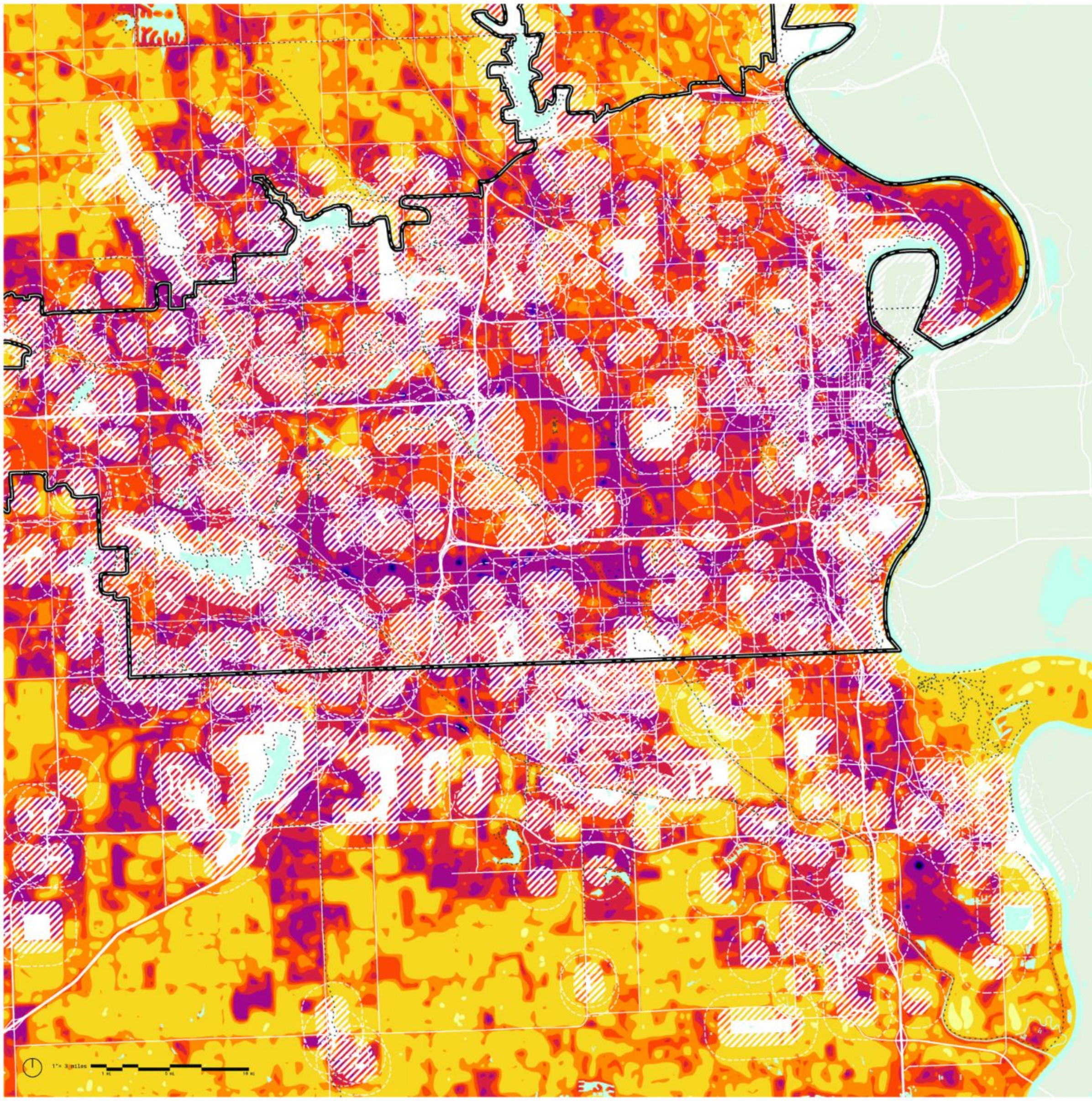

Figure 4. Land surface temperatures (Landsat Data) and urban green space in Omaha, NE.

b. *Data*

The study area for this research was the city of Omaha, Nebraska, USA. The data was collected using Geographic Information System (GIS) software. The data used in this portion of the methods included: Census Data from 2020, Tree Equity Score Data from 2020, and the shapefile from the previously defined heat islands of Omaha.

c. Heat Vulnerability Assessment

After locating the eight heat islands, more data was collected, including median income, the percentage of people of color, park tree equity score, trails, highways, bus stops, public transit, and health infrastructure. All layers were then clipped to the island boundary using a clip tool that cuts out a piece of one dataset using one or more features in another dataset as a cookie cutter. The island layers were exported to Illustrator and reassembled on top of each other to further investigate the layers and identify common patterns.

Starting with the base map, which includes the island and surrounding context, the second layer highlights the infrastructure, including the highway (represented in red), bus stops, and health infrastructure in the heat island area. The third layer is an environmental health, which includes the tree equity score (represented by a gradient color from light gray to dark green), parks (represented with white hatch), and trails (represented by dotted black lines). The last layer is sociodemographic, which includes the percentage of people of color (represented by red circles, with larger circles indicating higher numbers of people of color in that area), and median income (represented by a gradient color from gray to dark green, with darker colors indicating higher income levels).

Categories	**Potential Criteria**
Environment/Health	Contamination Ecological Systems Green Amenities Surface Temperature (Landsat)
Social/Economic	Ethnic Distribution Population Density Age Distribution Wealth Distribution
Physical Infrastructure	Traffic Volume Public Mobility Transportation Infrastructure Zoning

Table 2. Adaptation and Mitigation Strategies.

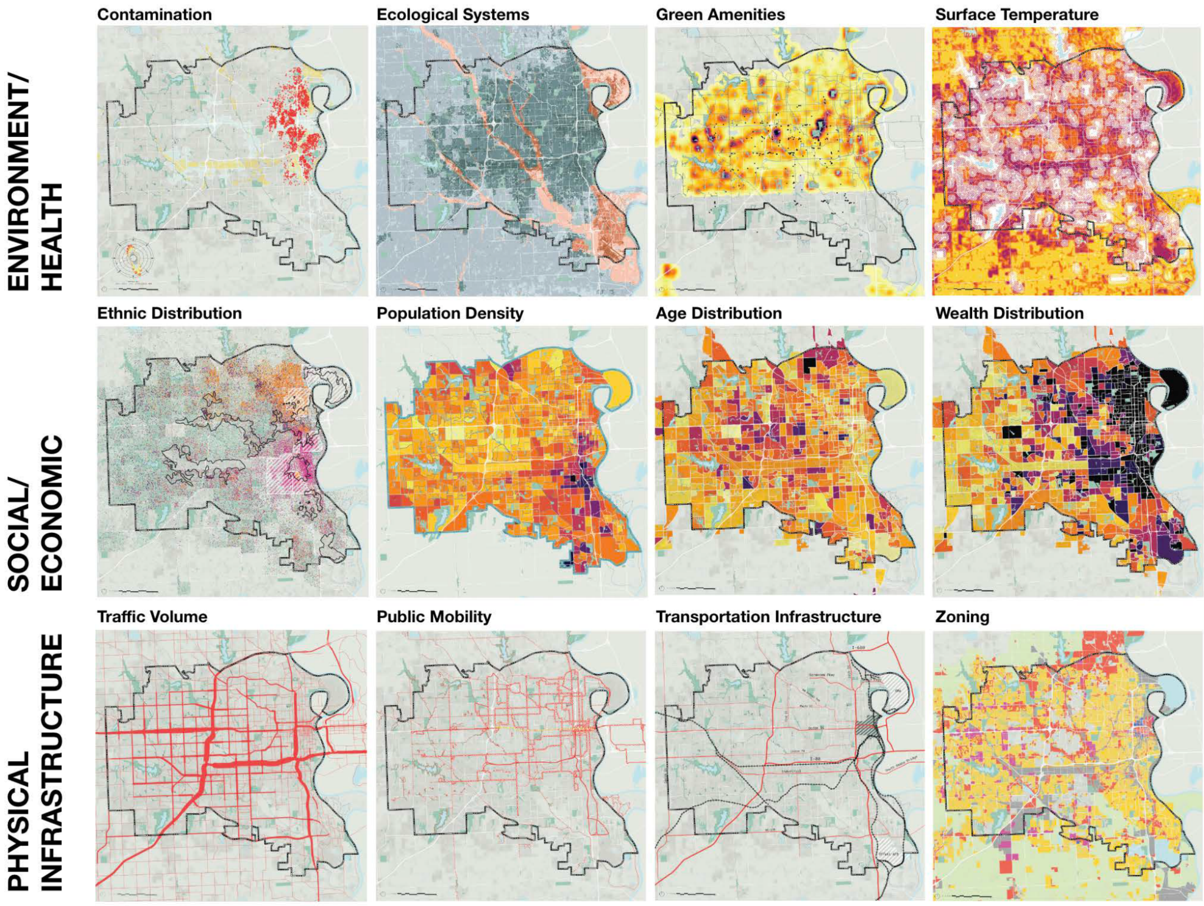

Figure 5. Conducting a heat vulnerability assessment by systems mapping the disproportionate impacts of heat.

d. *Isolating the Heat "Islands"*

Through comparing the heat vulnerability assessment to the land surface temperatures, heat "islands" were selected and isolated to better understand the criteria at a smaller scale. Environment/health, social/economic, and physical infrastructure data were mapped and compared to the city-wide data to better understand the extent of heat disparity in these "islands." The following metrics: average surface temperature, population, percent ethnic minority, poverty rate, household income, unemployment rate, physical health, and mental health, were compared to Omaha scale data. It was found that for all "islands," average surface temperature, percent ethnic minority, poverty rate, and unemployment rate were higher than the average data for Omaha. Household income, physical health, and mental health were lower on average.

Figure 6. Isolated heat "islands" with physical infrastructure mapping.

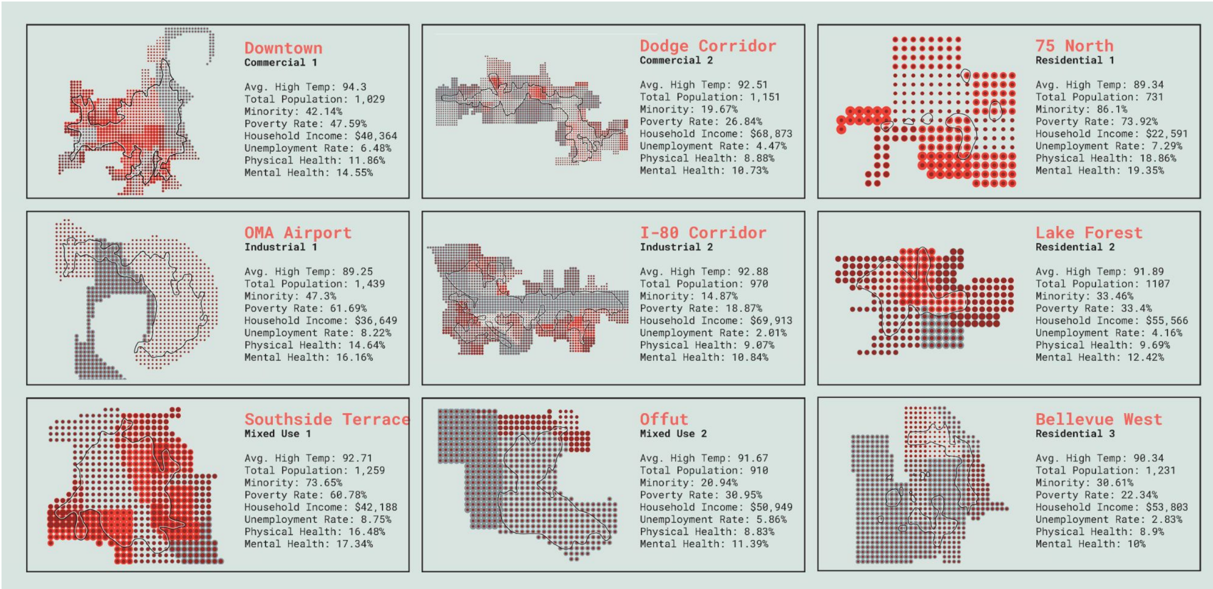

Figure 7. Measuring demographic data of the heat "islands" to the broader City of Omaha data.

e. *Correlating Heat Islands to Lack of Greenspace*

The lack of green space can worsen the heat island effect in urban areas. The heat island effect occurs when the temperature in an urban area is significantly higher than in the surrounding rural areas due to the absorption and retention of heat by buildings and pavement. Green spaces such as parks, trees, and vegetation provide shade and reduce the amount of heat absorbed by buildings and pavement. They also provide a cooling effect by reducing the amount of heat radiation absorbed by surfaces. When there is a lack of green space in urban areas, there are fewer opportunities for shade and cooling, resulting in higher temperatures. This can lead to a vicious cycle where higher temperatures lead to increased energy use for cooling, which in turn contributes to even higher temperatures due to the waste heat generated by air conditioning systems. Therefore, incorporating green space into urban planning can help mitigate the heat island effect and improve the quality of life for urban residents.

To guide the development of a heat action plan, the team began by compiling available resources and literature. It is not within the scope of this research to conduct a comprehensive literature review, although we found it necessary to develop a baseline understanding of available resources. A full list of references can be found at the end of this document. Two particular documents were referenced as primary sources to help guide this process: "Planning for Urban Heat Resilience" by Keith and Meerow, 2022 and "The Heat Action Platform" by the Adrienne Arsht-Rockefeller Foundation Resilience Center.

4. NEXT TASKS

The next tasks for the third quarterly report will focus on working with community members to collect qualitative data for the impacts of extreme heat on the ground. The increasing frequency and intensity of extreme heat in urban environments pose significant public health risks, with underserved populations disproportionately affected. While heat action plans have gained traction as a process for mitigating the unequal distribution of intense surface temperatures, there is a need for more granular data to guide site-scale landscape planning decisions. The prevailing method of measuring Land Surface Temperature (LST) using United States Geological Survey (USGS) remote sensing data can only reach a resolution of 30m x 30m, and often overlooks the lived reality of the impacts of extreme heat. By scaffolding the quantitative data collected in this research with qualitative survey data and heat walks, we can develop a stronger understanding of the tangible impacts of extreme heat.

5. REFERENCES

Abdoulaye, A. (2022). *Urban Heat Island Mapping Project* [Unpublished Manuscript]. Center for Environmental Health and Toxicology, University of Nebraska Medical Center.

Berko, J. (2014). *Deaths attributed to heat, cold, and other weather events in the United States, 2006-2010*. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.

Bloch, S. (2019, April 1). *Shade*. Places Journal. Retrieved September 20, 2022, from https://placesjournal.org/article/shade-an-urban-design-mandate/

Borunda, A. (2021, May 3). *Racist housing policies have created some oppressively hot neighborhoods*. Science. Retrieved October 2, 2022, from https://www.nationalgeographic.com/science/article/racist-housing-policies-created-some-oppressively-hot-neighborhoods#:~:text=A%20recent%20study%20found%20that,neighborhoods%20in%20the%20same%20city.

Ellenburg, K., Coleman, J., & Majarad, S. N. (2018). (rep.). *Service Learning Course Design Guide* (pp. 5–7). Knoxville, TN: University of Tennessee.

Environmental Protection Agency. (2017, October 20). *Omaha Lead Site Profile*. EPA. Retrieved October 2, 2022, from https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Cleanup&id=0703481#bkground

Environmental Protection Agency. (2022, July 21). *What You Can Do to Reduce Heat Islands*. EPA. Retrieved September 20, 2022, from https://www.epa.gov/heatislands/what-you-can-do-reduce-heat-islands

Environmental Protection Agency. (2022, April 18). *Heat Islands and Equity*. EPA. Retrieved September 20, 2022, from https://www.epa.gov/heatislands/heat-islands-and-equity

Guardaro, M., Messerschmidt, M., Hondula, D. M., Grimm, N. B., & Redman, C. L. (2020). Building Community Heat Action Plans Story by story: A three neighborhood case study. *Cities*, *107*, 102886. https://doi.org/10.1016/j.cities.2020.102886

The Heat Action Platform. Adrienne Arsht-Rockefeller Foundation Resilience Center. (2022, October 31). Retrieved April 25, 2023, from https://onebillionresilient.org/heat-action-platform/

Hoffman, J. S., Shandas, V., & Pendleton, N. (2020). The effects of historical housing policies on resident exposure to intra-urban heat: A study of 108 US urban areas. *Climate*, *8*(1), 12. https://doi.org/10.3390/cli8010012

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M. K., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K., & Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*, *21*(2). https://doi.org/10.5751/es-08373-210239

Keith, L., & Meerow, S. (2022). (rep.). *Planning for Urban Heat Resilience*. Chicago, IL: American Planning Association.

Massey, D. S., & Tannen, J. (2015). A research note on trends in black hypersegregation. *Demography*, *52*(3), 1025–1034. https://doi.org/10.1007/s13524-015-0381-6

Massey, D. S., & Denton, N. A. (1988). The dimensions of residential segregation. *Social Forces*, *67*(2), 281. https://doi.org/10.2307/2579183

Meerow, S., & Mitchell, C. L. (2017). Weathering the storm: The politics of urban climate change adaptation planning. *Environment and Planning A: Economy and Space*, *49*(11), 2619–2627. https://doi.org/10.1177/0308518x17735225

The Nature Conservancy. (2019). *Heat Action Planning Guide For Neighborhoods of Greater Phoenix*. Retrieved September 21, 2022, from https://www.nature.org/content/dam/tnc/nature/en/documents/Phoenix-Arizona-Heat-Action-Plan.pdf

Neira, M., & Prüss-Ustün, A. (2016). Preventing disease through Healthy Environments: A global assessment of the environmental burden of disease. *Toxicology Letters*, *259*. https://doi.org/10.1016/j.toxlet.2016.07.028

NOAA National Centers for Environmental Information, State of the Climate: Monthly Global Climate Report for August 2022, published online September 2022, retrieved on September 18, 2022 from https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202208.

UC Berkeley. (n.d.). *Most to least segregated cities in 2020*. Othering & Belonging Institute. Retrieved September 18, 2022, from https://belonging.berkeley.edu/most-least-segregated-cities-in-2020

US Climate Data. (2023) *Weather averages Omaha, Nebraska*. Temperature - Precipitation - Sunshine - Snowfall. (n.d.). Retrieved April 25, 2023, from https://www.usclimatedata.com/climate/omaha/nebraska/united-states/usne0363