Assessing Health Vulnerabilities to Heatwaves

Water, Climate and Health
Research Seminar Series

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Outline

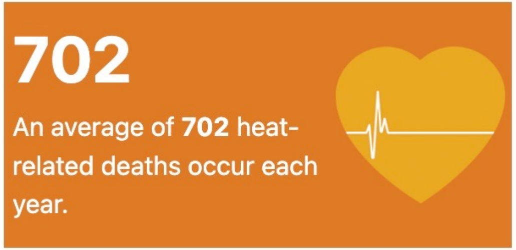
Introduction	• About Heatwaves and their trends in the United States • How to prevent its effects
Case Study 1	• Determining health vulnerabilities of heatwave in Nebraska
Case Study 2	• An example of a study to determine health risk of heatwave in a small city

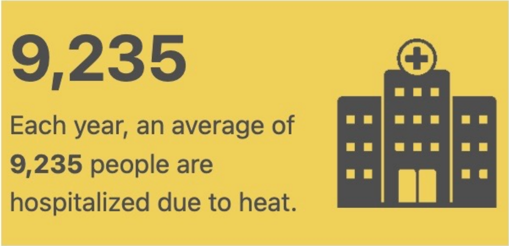
What is Heatwave

- Qualitative: A persistent period of unusually hot days (or nights)
- Quantitative: Many definitions → E.g.: Puvvula et. al, 2022[+] tested 28 heatwave definitions over NC to distinguish the best matching related health data

From CDC: Did you know in the United States...

*



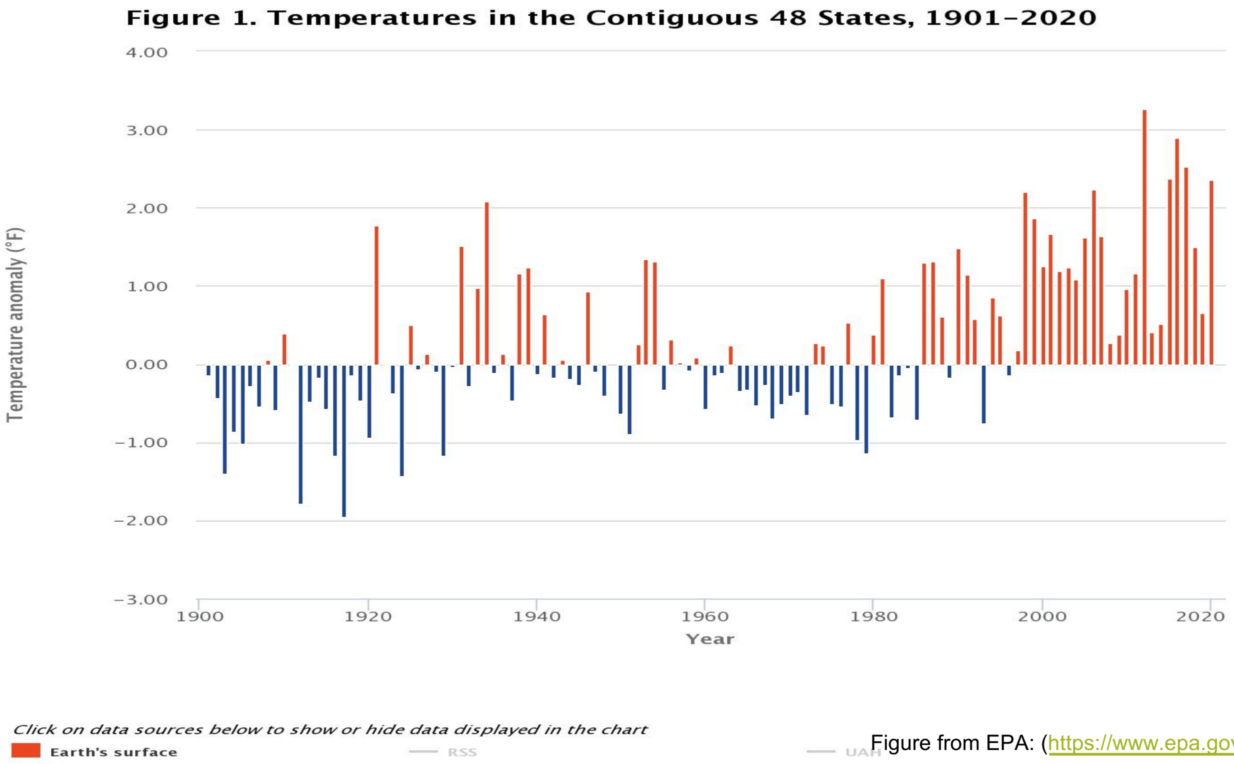


* Picture from CDC website at this address: (https://ephtracking.cdc.gov/Applications/heatTracker/)

+ Puvvula, J., Abadi, A.M., Conlon, K.C., Rennie, J.J., Jones, H. and Bell, J.E., 2022. Evaluating the sensitivity of heat wave definitions among North Carolina physiographic regions. *International journal of environmental research and public health*, *19*(16), p.10108.

Changes in Temperature

Past:



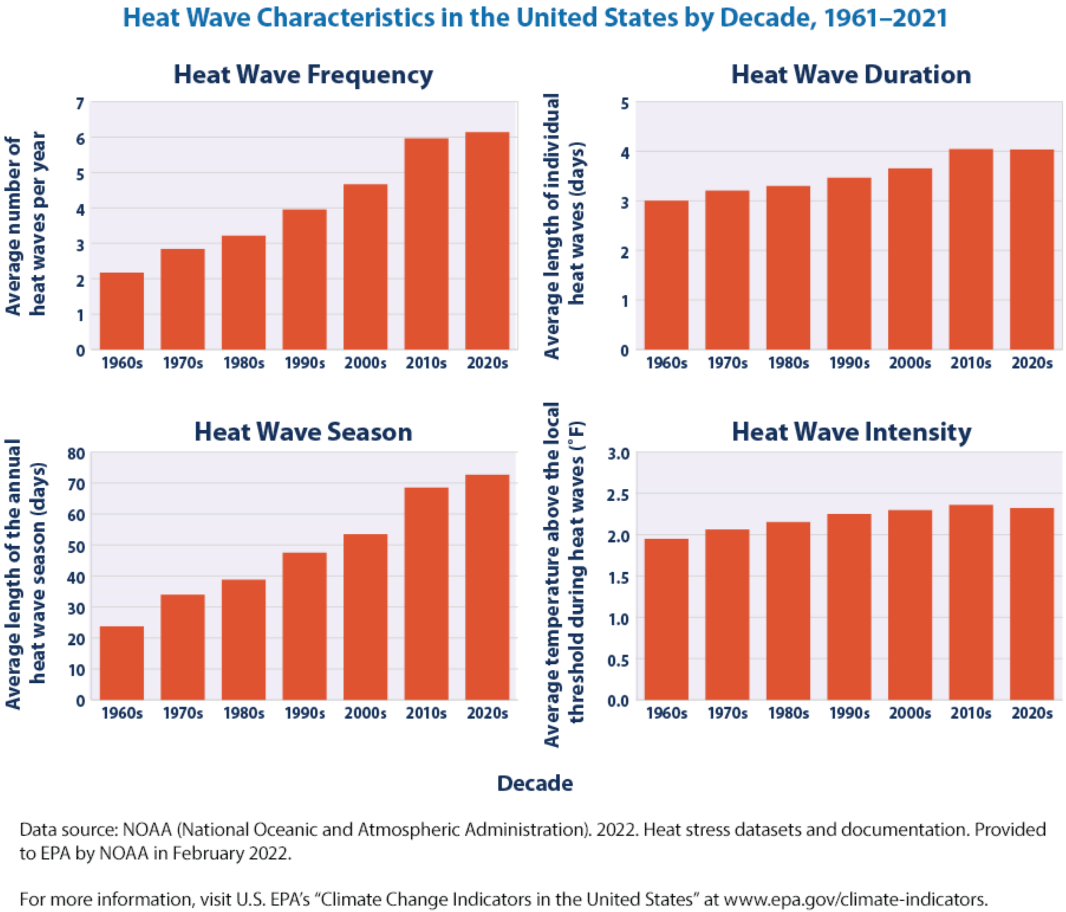
Future:

- Significant increases in the number of extreme hot days for most of urban areas
- Upward warming and more severe heatwaves in a global scale in 21st century.

(1901–2000 average as a baseline)

Figure from EPA: (https://www.epa.gov/climate-indicators/climate-change-indicators-heat-waves)

How Heat Waves are Changing in The US?



- Average Number of heat waves : 2.86 times more
- Duration: > 34% Increase
- Average length of heatwave season: ~ 2.8 times Increase
- Average temperature above local threshold: %19 Increase

- Frequency: the number of heat waves that occur every year.
- Duration: the length of each individual heat wave, in days.
- Season length: the number of days between the first heat wave of the year and the last.
- Intensity: how hot it is during the heat wave.

Figure from EPA: (https://www.epa.gov/climate-indicators/climate-change-indicators-heat-waves)

How to Reduce the Effects of Heatwaves

- Adaptation Plans
  - Heatwave Early Warning
  - Cooling Centers
  - Heat action plans
  - Healthcare preparation plans

- Mitigation Plans
  - Increasing Green areas
  - Increasing Shades
  - Green roofs / Cool roofs
  - Light colored roads

Heat Vulnerability Index (HVI)

Purpose	To distinguish the levels of community vulnerability to heatwave
Usage	As a **planning tool** to distinguish high priority areas for interventions (allocate appropriate adaptation or mitigation).
Components	• Social Vulnerability Index (SVI) • Environmental Vulnerability Index (EVI)

Mapping Heat Vulnerability Index Based on Different Urbanization Levels in Nebraska, USA*

Key Points of Study

- Despite similar incidence rates, Heat Vulnerability Index (HVI) in rural areas is under studied in comparison to urban areas
- The environmental vulnerability variables in rural areas are dissimilar to urban areas, so we applied different variables to calculate them
- We found different organization of socioeconomic variables in calculated HVIs, suggesting separate heat strategies for urbanization levels

*Jalalzadeh Fard, B., Mahmood, R., Hayes, M., Rowe, C., Abadi, A.M., Shulski, M., Medcalf, S., Lookadoo, R. and Bell, J.E., 2021. Mapping heat vulnerability index based on different urbanization levels in Nebraska, USA. *GeoHealth*, *5*(10), p.e2021GH000478.
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021GH000478

Steps in Creating HVI Maps for Nebraska

1. Choosing Socioeconomic Variables
2. Categorizing Areas (Census Tracts)
3. Choosing Environmental Variables
4. Grouping variables into intervention groups (Using PCA)
5. Map

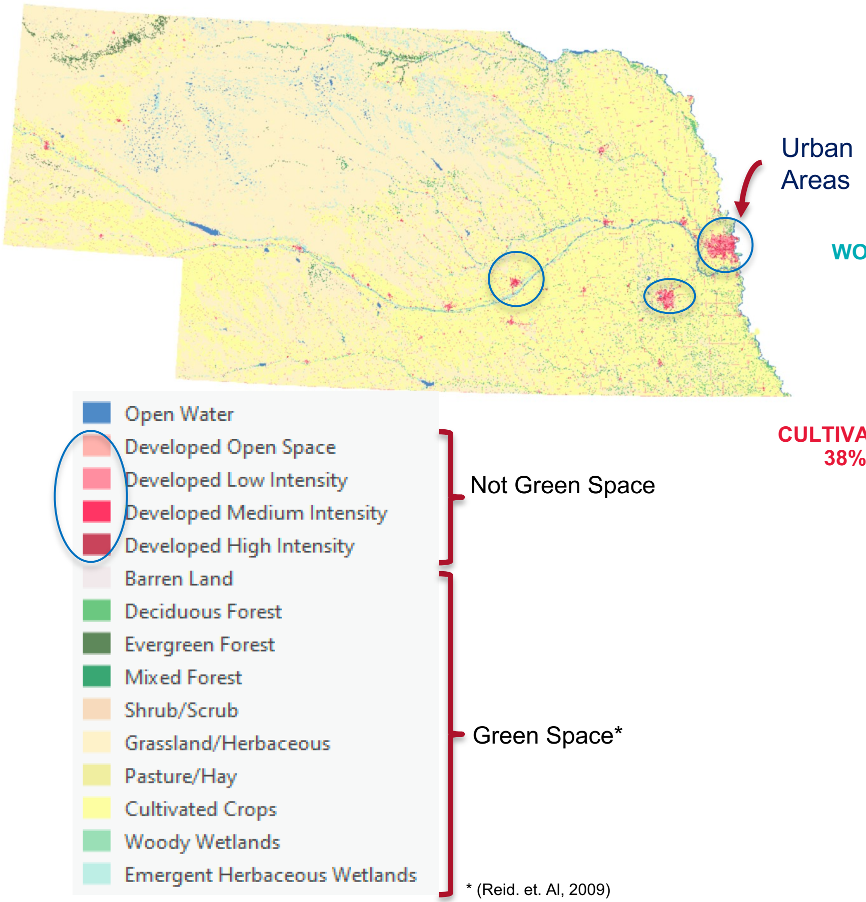
A. Choosing Socioeconomic Variables

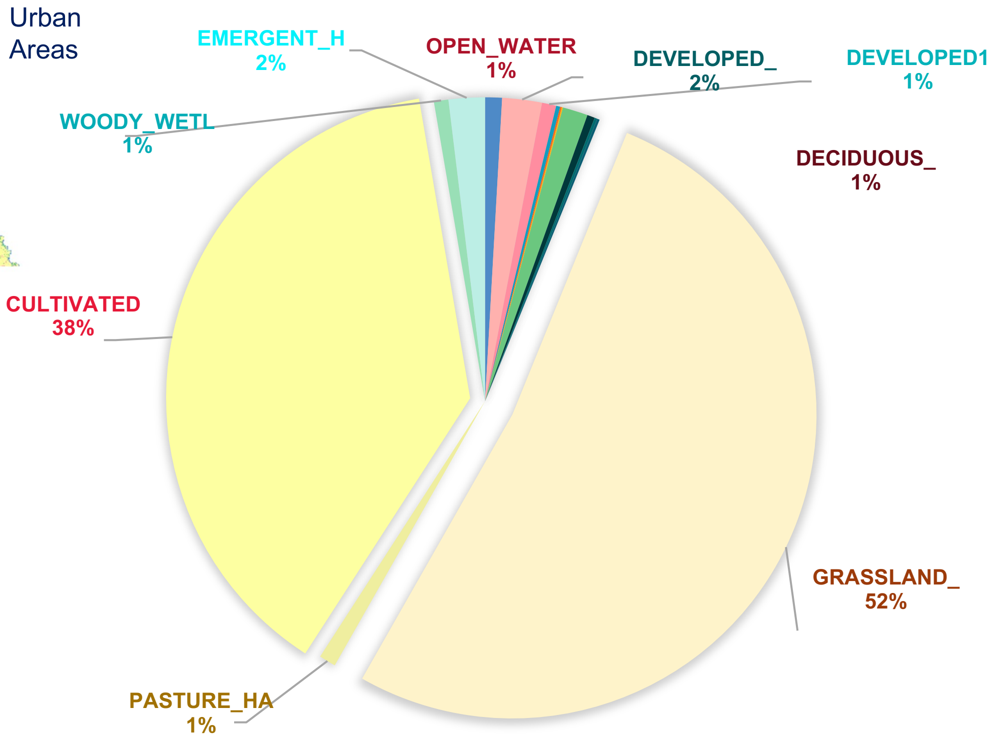
Considered Socioeconomic Variables	Name
1. % population 18 to 64 with disability	Disability
2. % population over 25 and education high school diploma or lower	Education
3. % Speaking English less than very well	Language
4. % Over 60	elderly
5. % Over 60, living alone	Elderly, alone
6. % Below poverty level *	Poverty
7. % Races o/ white	Race

Data Source : ACS 2016, 5-year estimates

* Following the Office of Management and Budget's (OMB) Statistical Policy Directive 14, the Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who is in poverty. If a family's total income is less than the family's threshold, then that family and every individual in it is considered in poverty. The official poverty thresholds do not vary geographically, but they are updated for inflation using the Consumer Price Index (CPI-U). The official poverty definition uses money income before taxes and does not include capital gains or noncash benefits (such as public housing, Medicaid, and food stamps).

B. Environmental Variables
Land Cover Type (NLCD 2016) for Environmental Vulnerability (EVI)

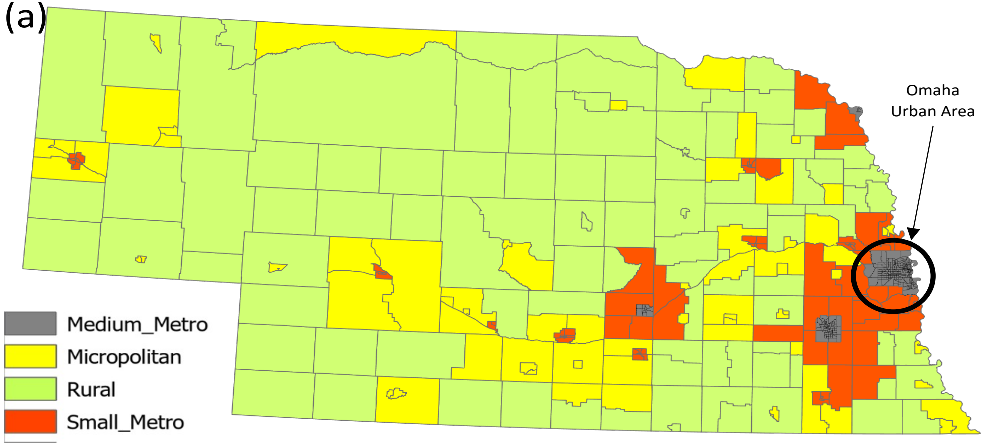




* (Reid. et. Al, 2009)

Categorizing Tracts from Land Type

(a)



Classified Census tracts (*Total n= 532*)

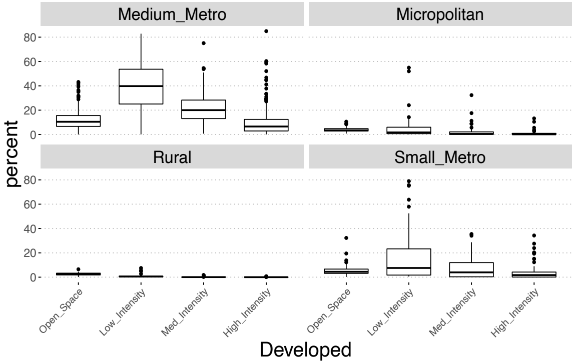
From [NCHS Urban Classes] and [RUCA]

(b)

	Urban Class	% Average Developed Area (NLCD 2016)	Number of Census Tracts
Urban	Medium Metro	84	280
Non-Urban	Small Metro	36	85
	Micropolitan	13	72
	Rural	4	95

Tracts in each Urban Type

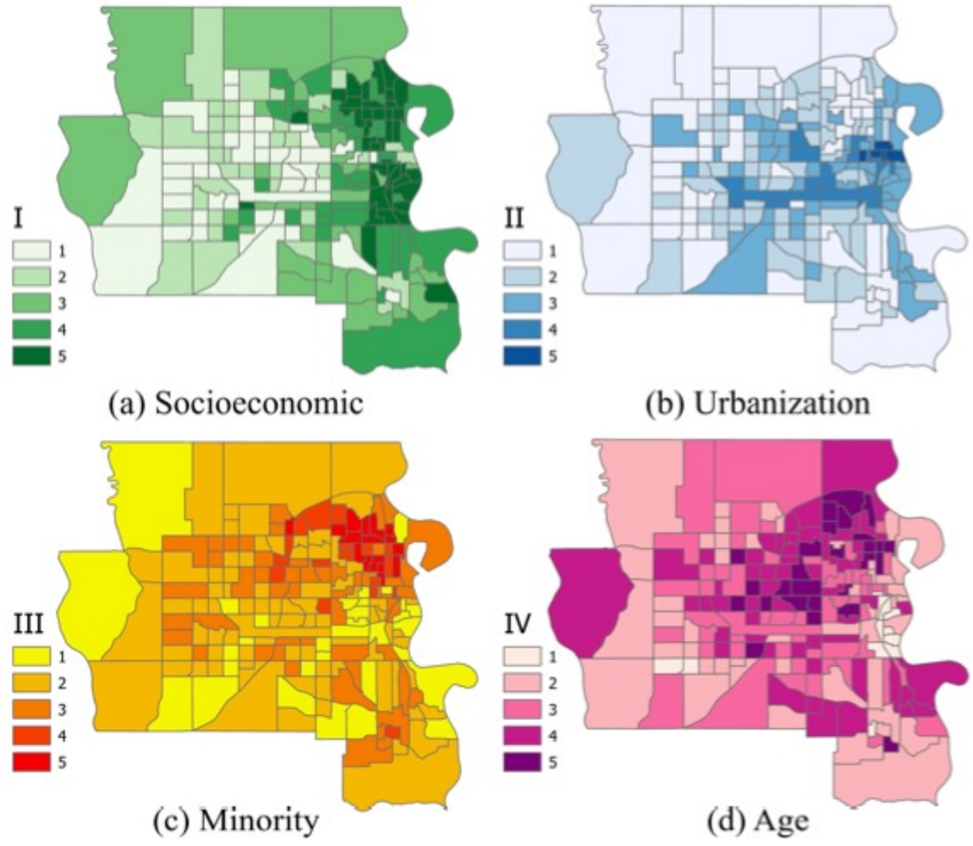
(c)



- Urban areas (Medium Metro) highest in number, but smallest in area
- Low Density Developed areas are largest area among all four developed types
- Other three urban classifications have very small percentages of developed land type

We cannot use the same Environmental Variables for all urban classes

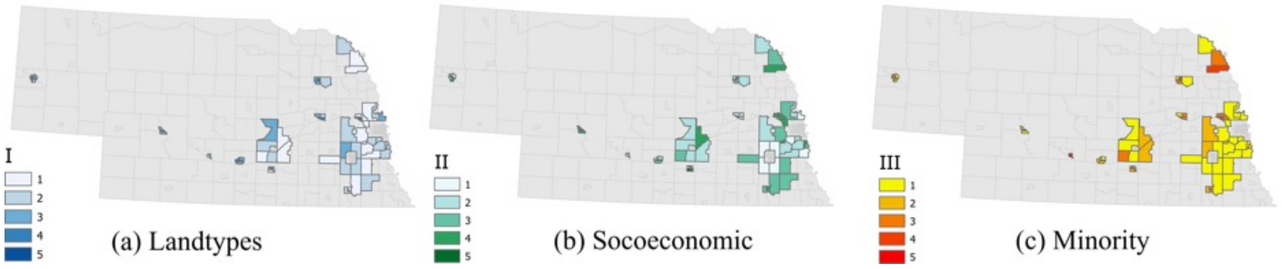
Vulnerability Levels for Omaha Urban Area



Category	Included Variables
Socioeconomic	Disability, Education, Poverty
Urbanization	Medium Developed, High Developed, Elderly Alone
Minority	Language, Race
Age	Over 60

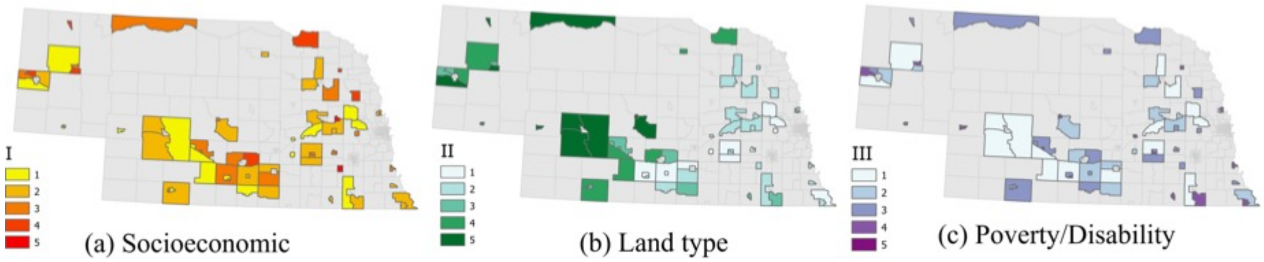
Four Heat Vulnerability Classes in Omaha Area

HVI Levels



Small Metro

Category	Included Variables
Landtypes	Class 1 land, Class 2 land
Socioeconomic	Disability, Elderly alone, poverty
Minority	Language, Education, Race

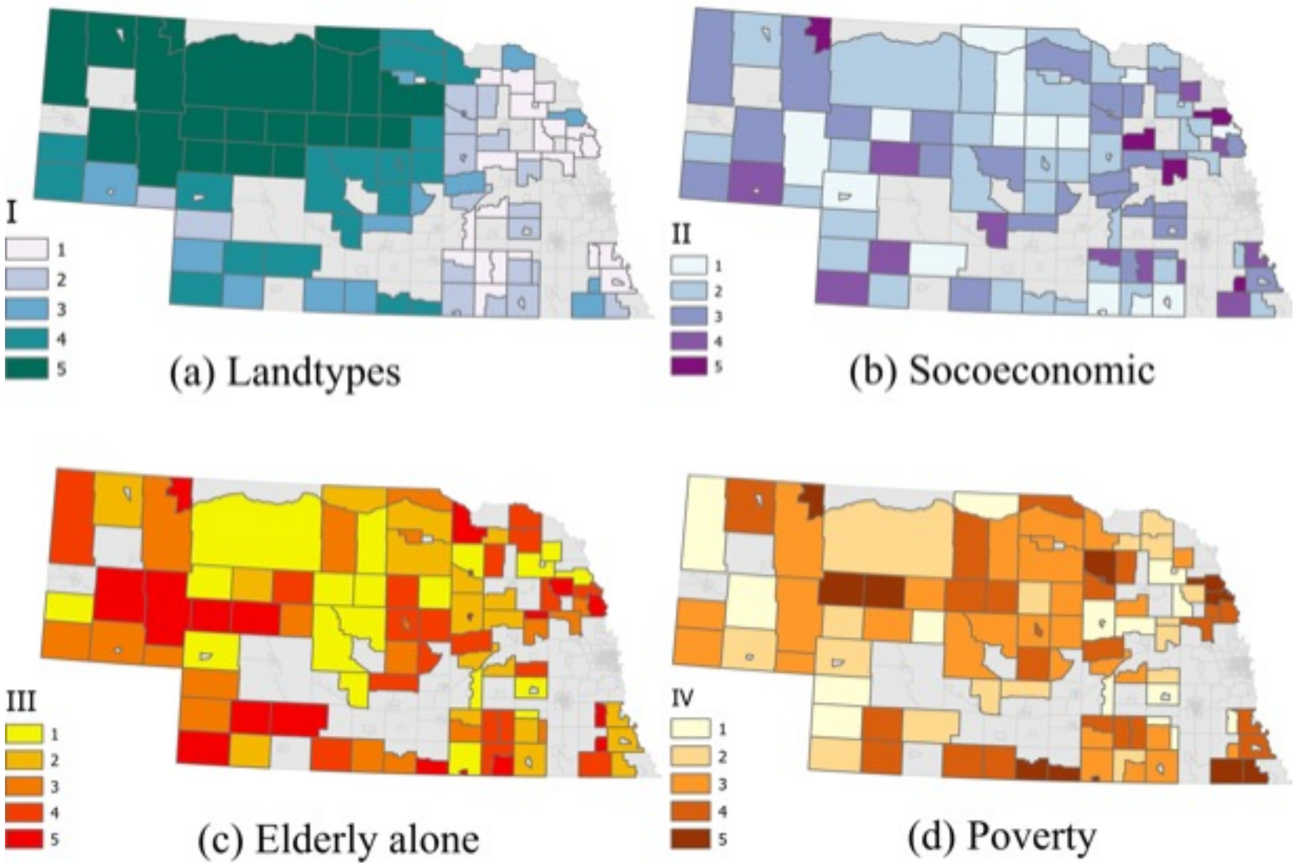


Micropolitan

Category	Included Variables
Socioeconomic	Education, Language, Elderly, Race
Landtype	Class 2 Land, Class 3 land
Poverty/Disability	Disability, Elderly alone, Poverty

Class1 (consists of the four developed land types and Barren Land),
Class 2 (includes Deciduous Forest, Evergreen Forest, Mixed Forest, and Cultivated Crops),
Class 3 (composed of Shrub/Scrub, Grassland/Herbaceous, and Pasture/Hay), and
Class 4 (includes Woody Wetlands and Open Water).

HVI in Rural Areas

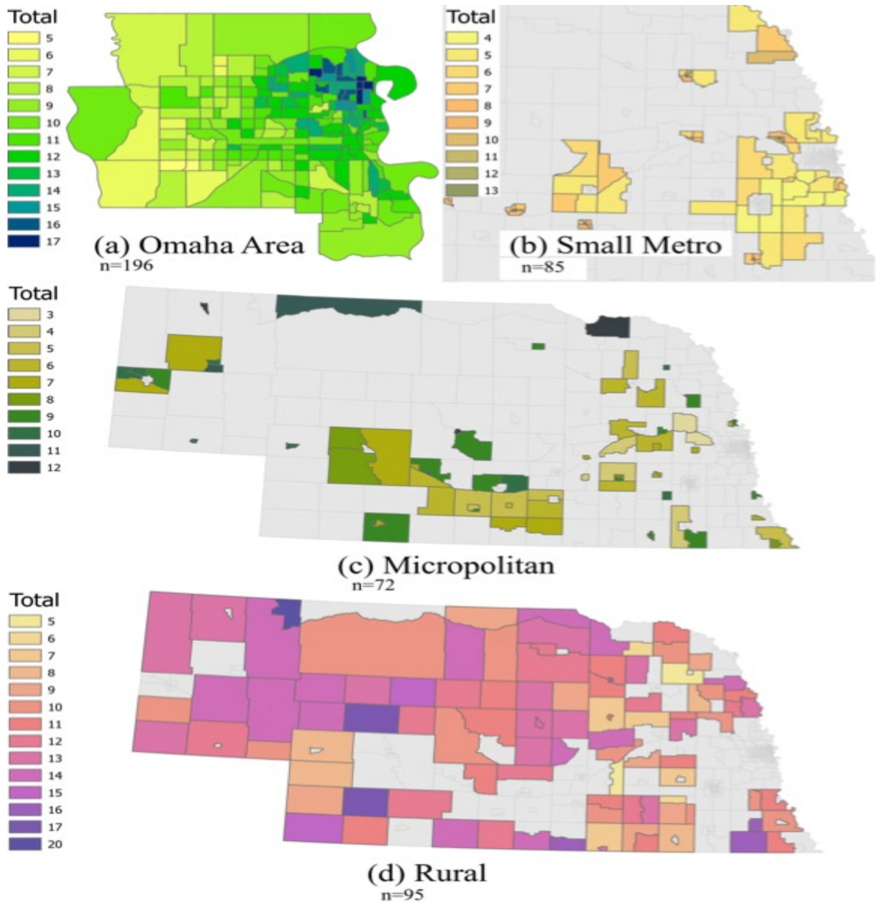


Category	Included Variables
Landtypes	Class 2 land, Class 3 land
Socioeconomic	Education, Elderly, Race
Elderly alone	Elderly Alone
Age	Elderly

Total Vulnerability Levels

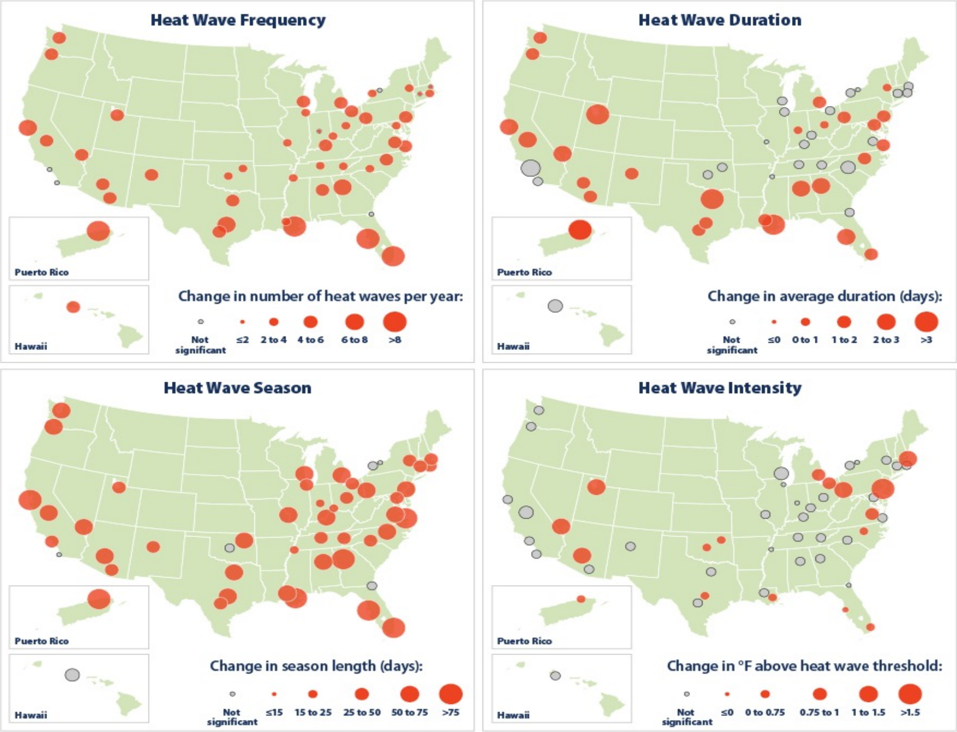
Conclusion

- We showed that separating heterogeneous study areas into different groups can reveal different structures of socioeconomic variables in the development of HVI
- These results can better help decision makers at various levels to focus on customized solutions for each urbanization level of residence.
- similar frameworks can be applied to other regions that contain similar heterogeneity.



Zooming in: A City Scale Health Vulnerability and Risk Mapping of Heatwave

Heat Wave Characteristics in 50 Large U.S. Cities, 1961–2021



Data source: NOAA (National Oceanic and Atmospheric Administration). 2022. Heat stress datasets and documentation. Provided to EPA by NOAA in February 2022.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

- 43 cities have higher than 2 times increase in frequency
- 10 out of 50 higher than 2 times increase in Duration
- All cities show increase in heatwave season with average of 51 days
- Average intensity has increased 0.5 F

- Frequency: the number of heat waves that occur every year.
- Duration: the length of each individual heat wave, in days.
- Season length: the number of days between the first heat wave of the year and the last.
- Intensity: how hot it is during the heat wave.

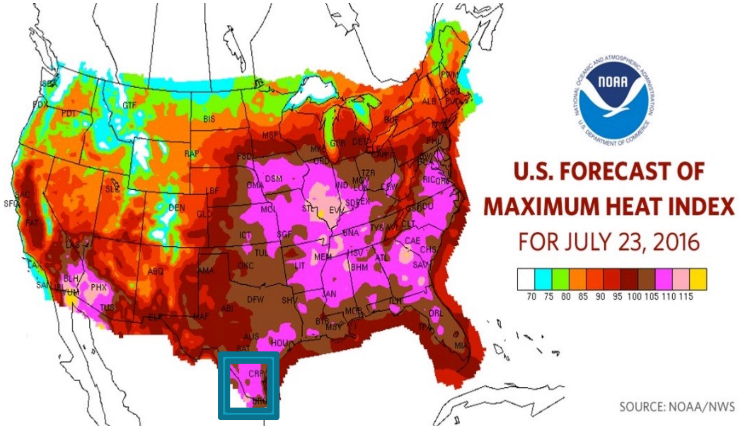
Figure from EPA: (https://www.epa.gov/climate-indicators/climate-change-indicators-heat-waves)

* Heatwaves are compared to local thresholds

Categorizing Areas – The Rationale

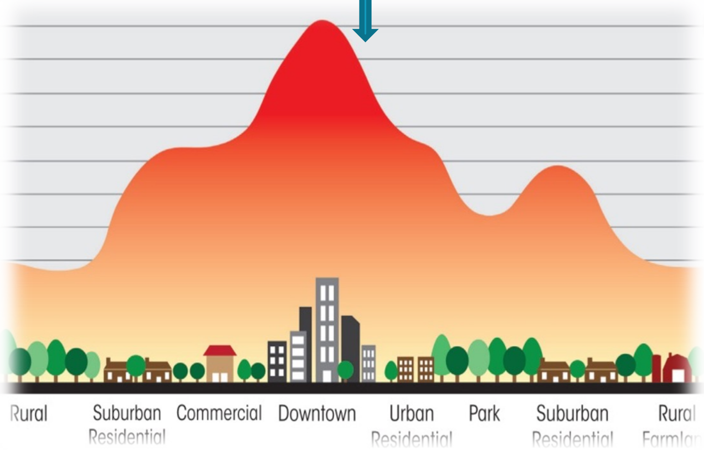
Heatwave
(Prolonged period of extraordinary hot temp)

a. Regional/Global scale : from GCMs



b. Local/Urban scale: Urban Heat Islands (UHI)

- Intensifies Heatwave in Urban areas



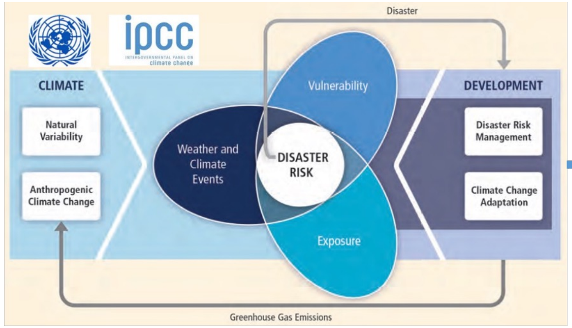
Separate into Urban / Rural

Urban Heat Islands (UHI) Are Important in Urban Areas

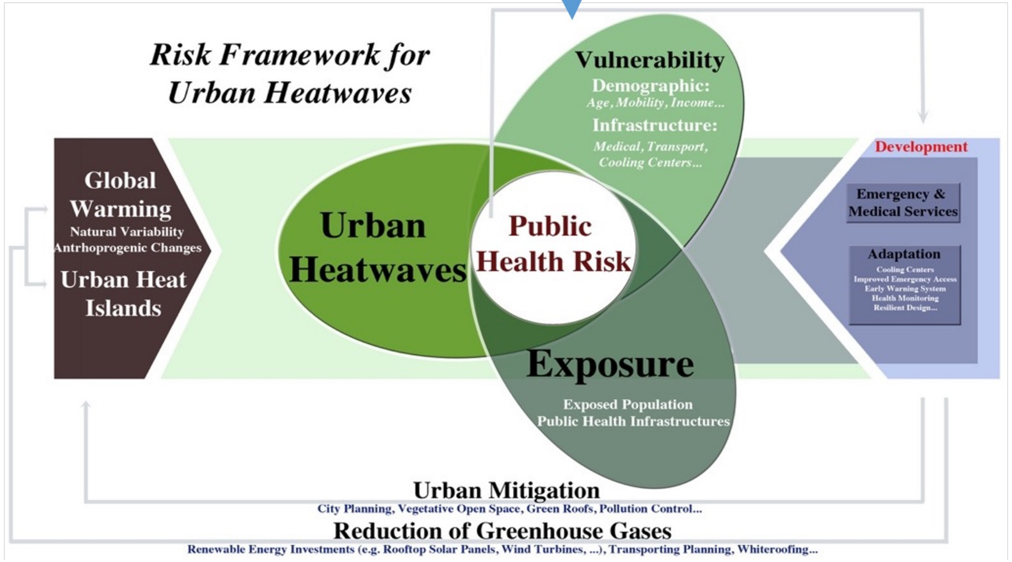
An urban heat island occurs when a city experiences much warmer temperatures than nearby rural areas. The difference in temperature between urban and less-developed rural areas has to do with how well the surfaces in each environment absorb and hold heat.

Building Community Resilience to Extreme Heat – 2016~17

Brookline, Massachusetts



Use adapted IPCC Risk Framework to guide research



A collaboration between Northeastern University, Thriving Earth Exchange, and climate Action office of the town of Brookline, MA

https://thrivingearthexchange.org/project/brookline-ma/

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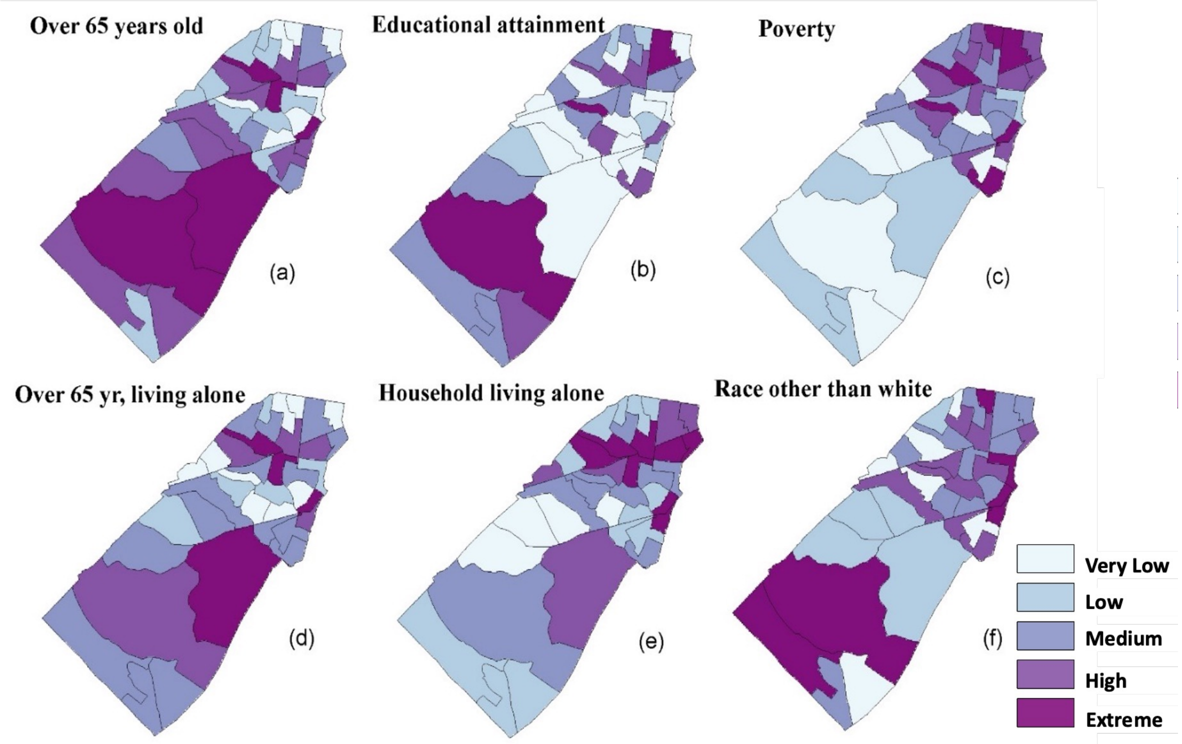
NSF BIGDATA award # 1447587, Expeditions in Computing Award #1029711, and Cyber SEES award #

Defining Vulnerability Variables



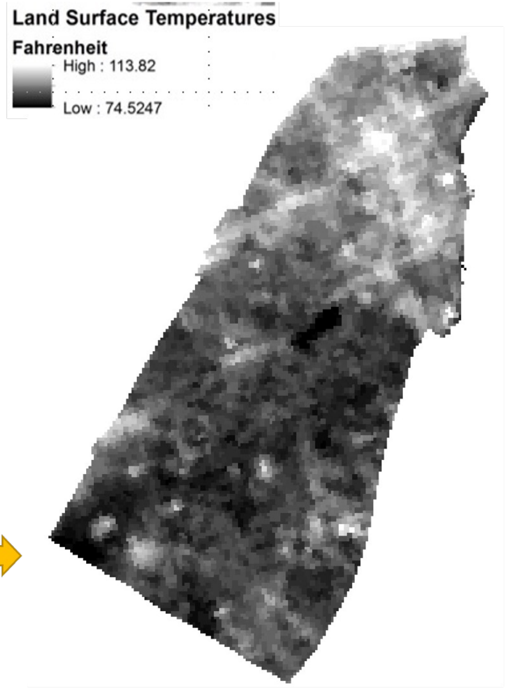
Census Block Groups

Measuring UHI using Satellite

- The heatwave periods (three or more consecutive days with maximum temperature of 90 degrees Fahrenheit, or higher) calculated from CDO database are compared with the available remote sensing images of the study area.

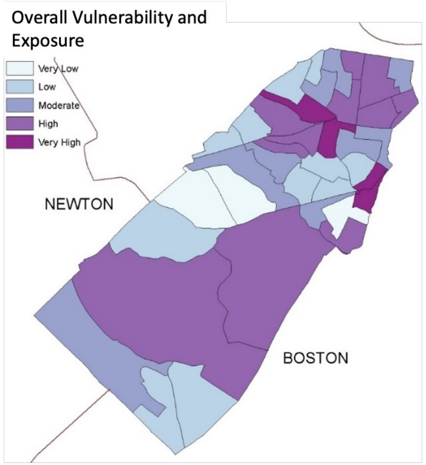
- June 27, 2007 was selected as the most recent available period during which a heatwave occurred and remote sensing data was available through Web-Enabled Landsat Data (WELD) system.

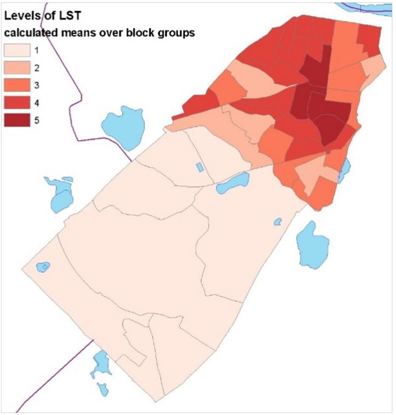
HEAT WAVE
(Jun 27, 2007) → WELD* →



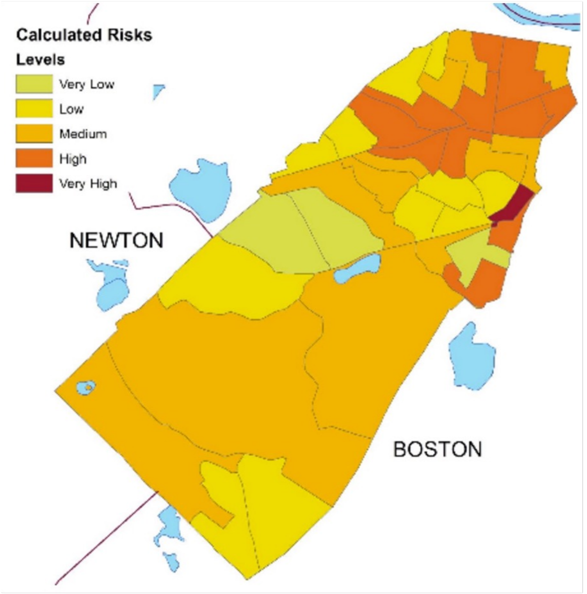
LST calculated from LandSat image on Jun 27, 2007, a heatwave period (30m x 30m resolution)

Risk Mapping

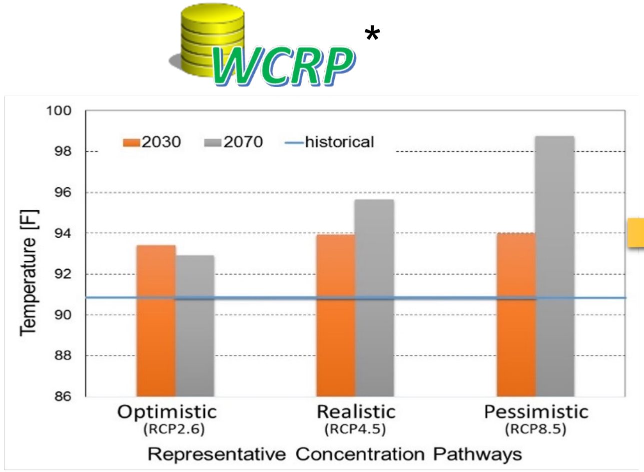




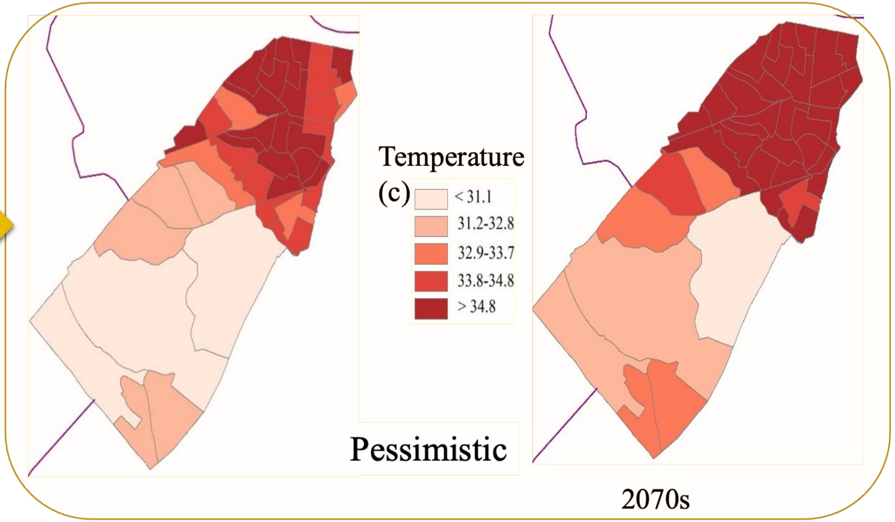
Hazard Levels (Mean of Land Surface Temperatures in each Block Group)



Future Projections of Hazard (LST)

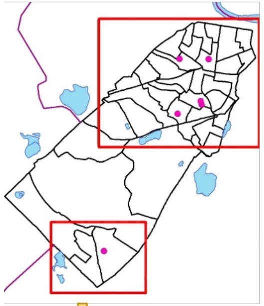


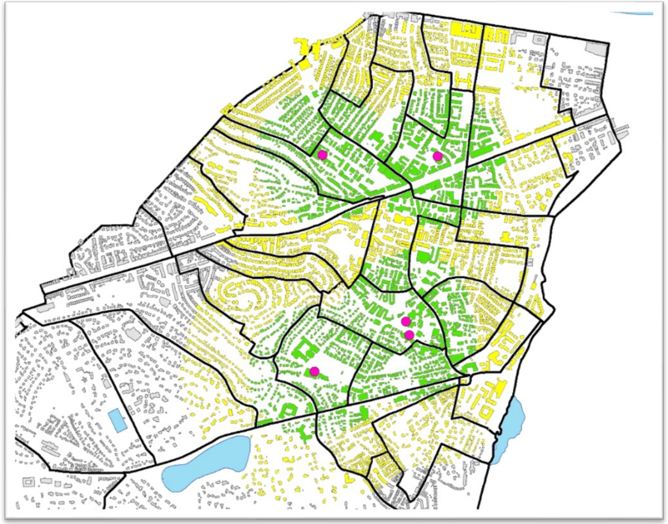
Changes in the 95th percentiles temperatures for the summer maximum surface air temperatures from WCRP model[6] for the study periods (2035-2064 and 2055-2084) are used as the threshold values for future projections



* Maurer, E. P., L. Brekke, and T. Pruitt. 2007. "Fine-resolution Climate Projections Enhance Regional Climate Change Impact Studies." Eos, Transactions, American Geophysical Union . Wiley Online Library. http://onlinelibrary.wiley.com/doi/10.1029/2007EO470006/full.

Adaptation: Cooling Centers





- 61.4% of all buildings are in less than ½ mile distance to a cooling center
- Over 80% buildings in high hazard areas are less than ½ mile to a cooling center

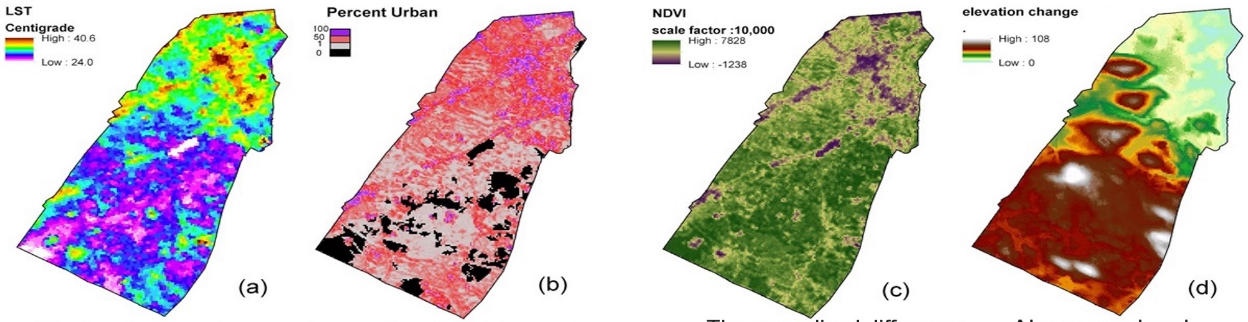
< ¼ mile distance

¼ < mile distance < ½

- ½ mile: 10 min comfortable walking speed for over 60
- ¼ mile: 5 minute walk in comfortable speed for over 60

Based on available public cooling centers, Summer 2016.

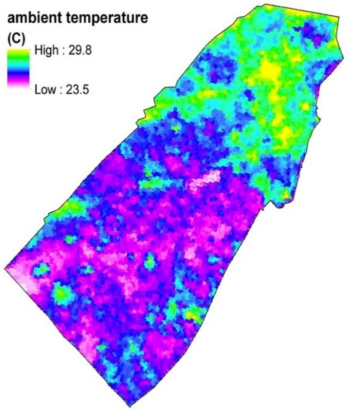
Ambient Temperature (Ta) is Needed for effective planning



Land Surface Temperature | Percent Developed Imperviousness | The normalized difference vegetation index | Above sea level

$$T_a = a_0 + a_1 T_{L,i} + a_2 U_i + a_3 N_i + a_4 El_i$$

- Usually Ta values not available in fine resolutions
- Therefore, we used four other variables to estimate Ta in 30x30m resolution*



Problems

- Calculated Ta Can be very inaccurate
- Initial variables may be different by locations

* Kloog, I., Nordio, F., Coull, B.A. and Schwartz, J., 2014. Predicting spatiotemporal mean air temperature using MODIS satellite surface temperature measurements across the Northeastern USA. *Remote sensing of environment*, *150*, pp.132-139.

There is good News for Omaha!

Omaha Urban Heat Watch Project, Aug 2022

- Ambient temperatures were captured during a hot day
- It contained community engagement

Stay for the next presentation!

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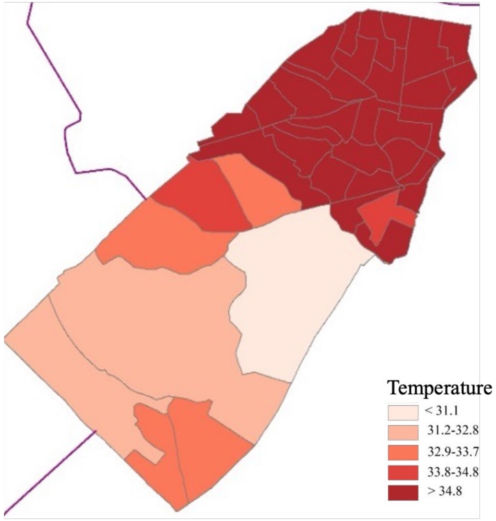
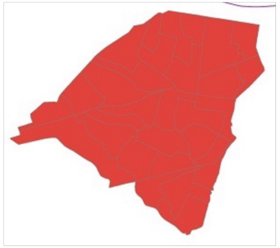
Appendix

Tree Canopy Analysis – Scenario I



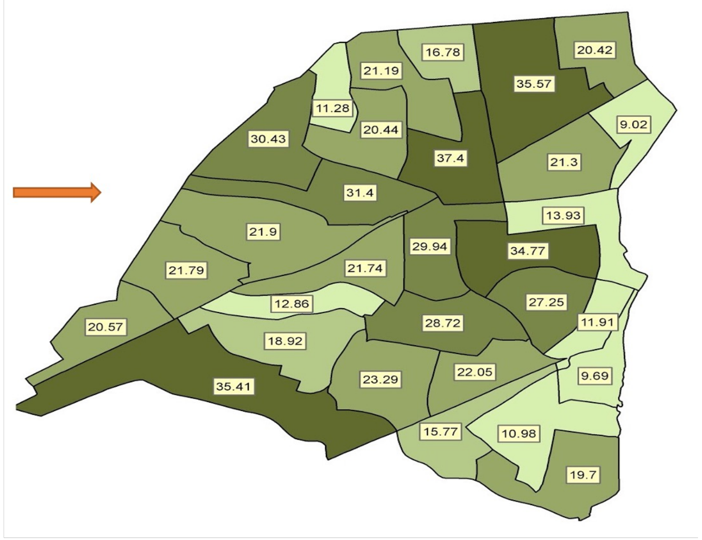
Change in hazard levels in 2070, worst case scenario



Target Temperature (c)

34.3 C

bringing highest hazard areas one level down

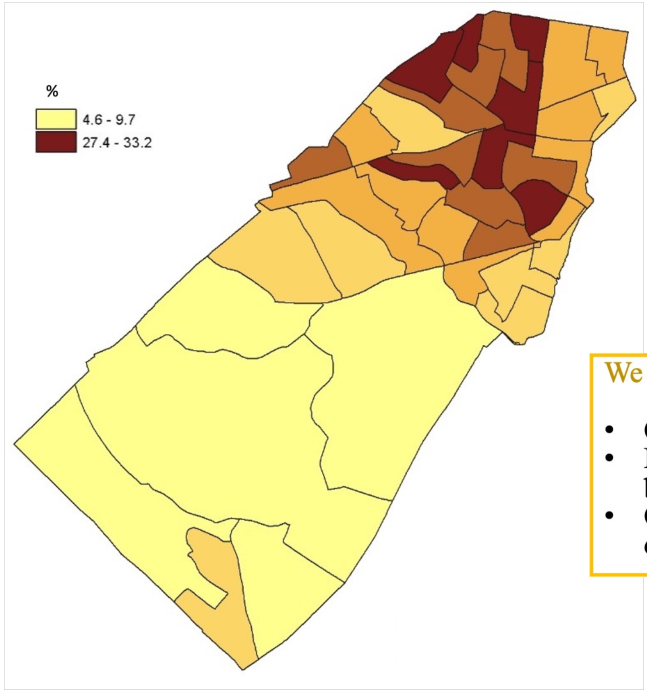


Calculated area of required added tree canopies (acres)

Roof Area Availability Analysis- For possibility of roof mitigation strategies

Roof Improvement Methods:

- Green Roofs
  - may be as simple as thin layers of vegetation, or as complex as a full garden with trees
- Reflective Roofs
  - To reflect more sunlight than a regular roof
  - Highly reflective paint, sheet covering, or highly reflective tiles or shingles.



We suggest a detailed study considering:

- Climate adaptability to Brookline
- Life Cycle Analysis of costs and benefits in local and regional scale
- Considering what-if scenarios for different situations

Classifying Land Types based on summer NDVI values

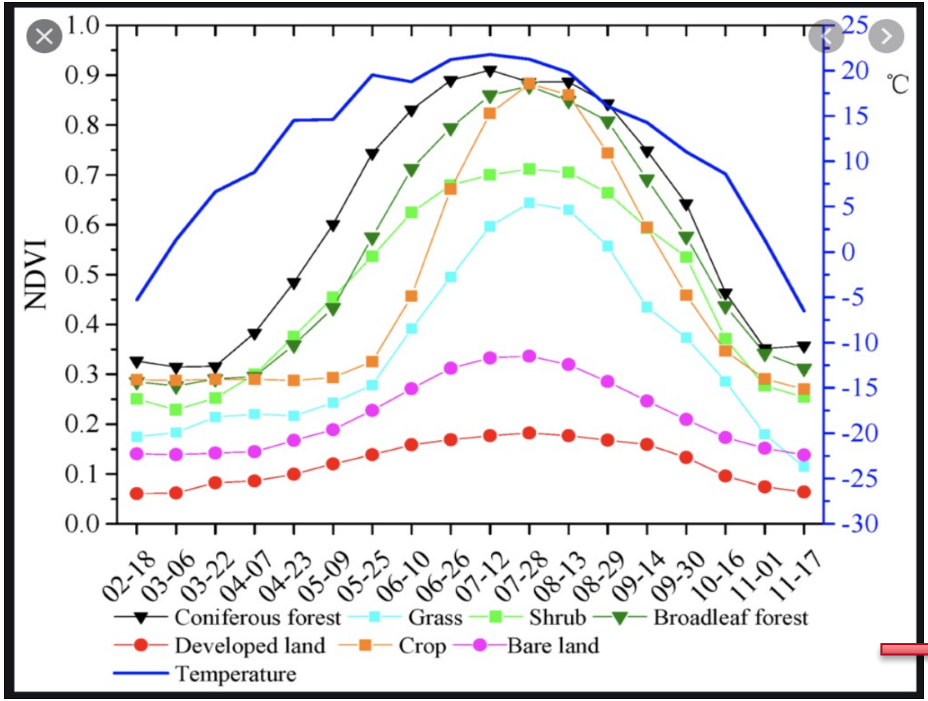


Fig s3. change of NDVI in different months for different land types. (figure from Kong F, Li X, Wang H, Xie D, Li X, Bai Y. Land cover classification based on fused data from GF-1 and MODIS NDVI time series. Remote Sensing. 2016 Sep;8(9):741.

class1 : Developed, BARREN_LAN
class2 : DECIDUOUS_, EVERGREEN_, MIXED_FORE, CULTIVATED
class3 : SHRUB_SCRU, GRASSLAND_, PASTURE_HA
class4 : WOODY_WETL, OPEN_WATER

Building Community Resilience to Extreme Heat in Historically Redlined Districts of Omaha-Nebraska

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Heat Watch Engagement Framework

1

Engage communities in describing and localizing climate-induced hazards

2

Develop analytical tools for examining scenarios of adaptation actions

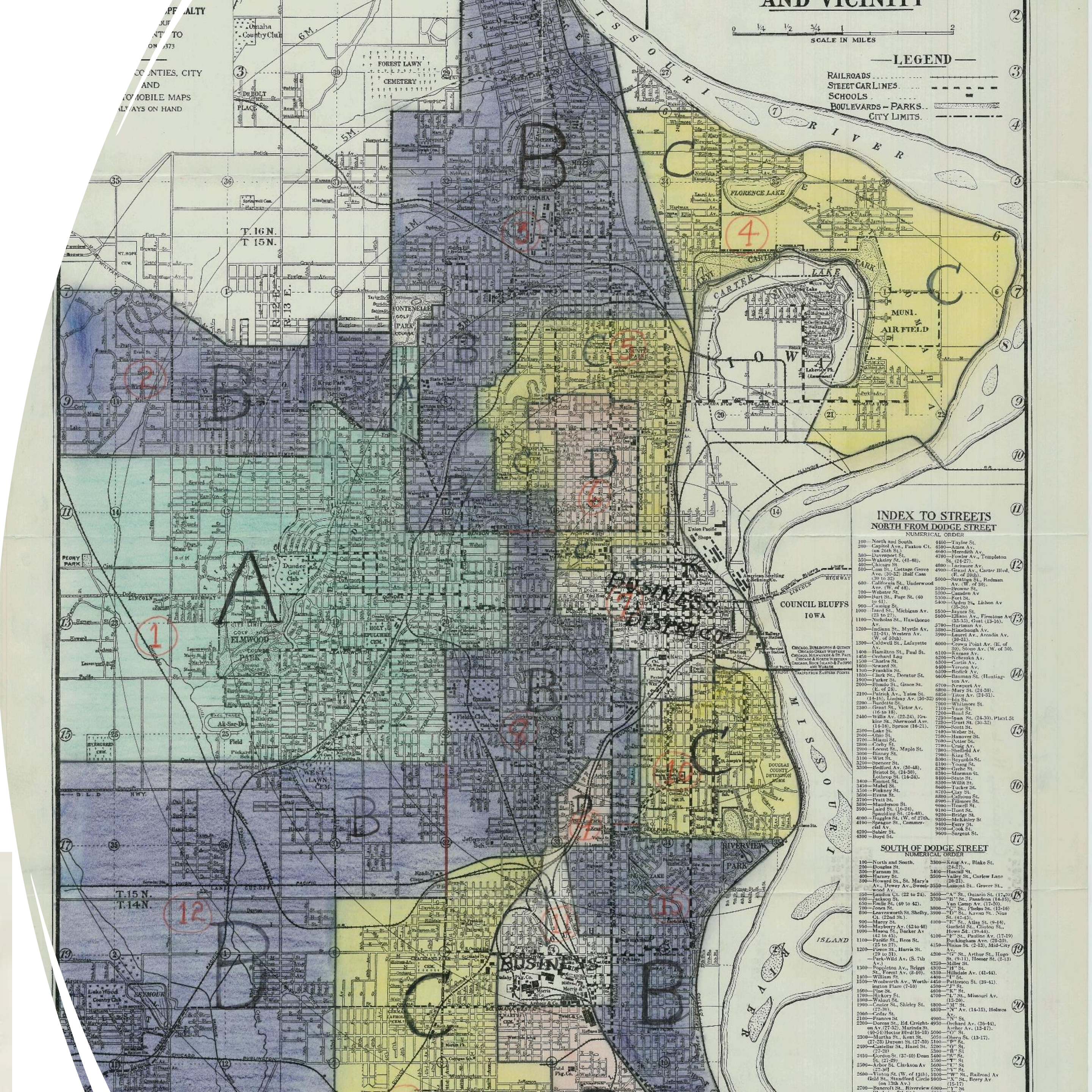
3

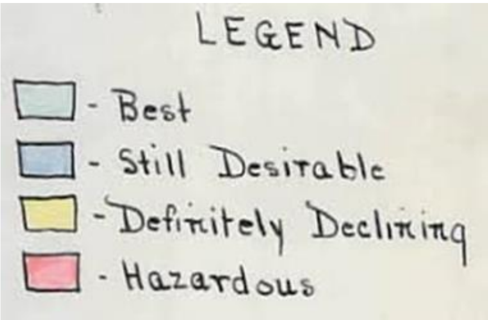
Support capacity-building efforts through the engagement of decision-makers and community groups

Discriminatory Practice of Redlining

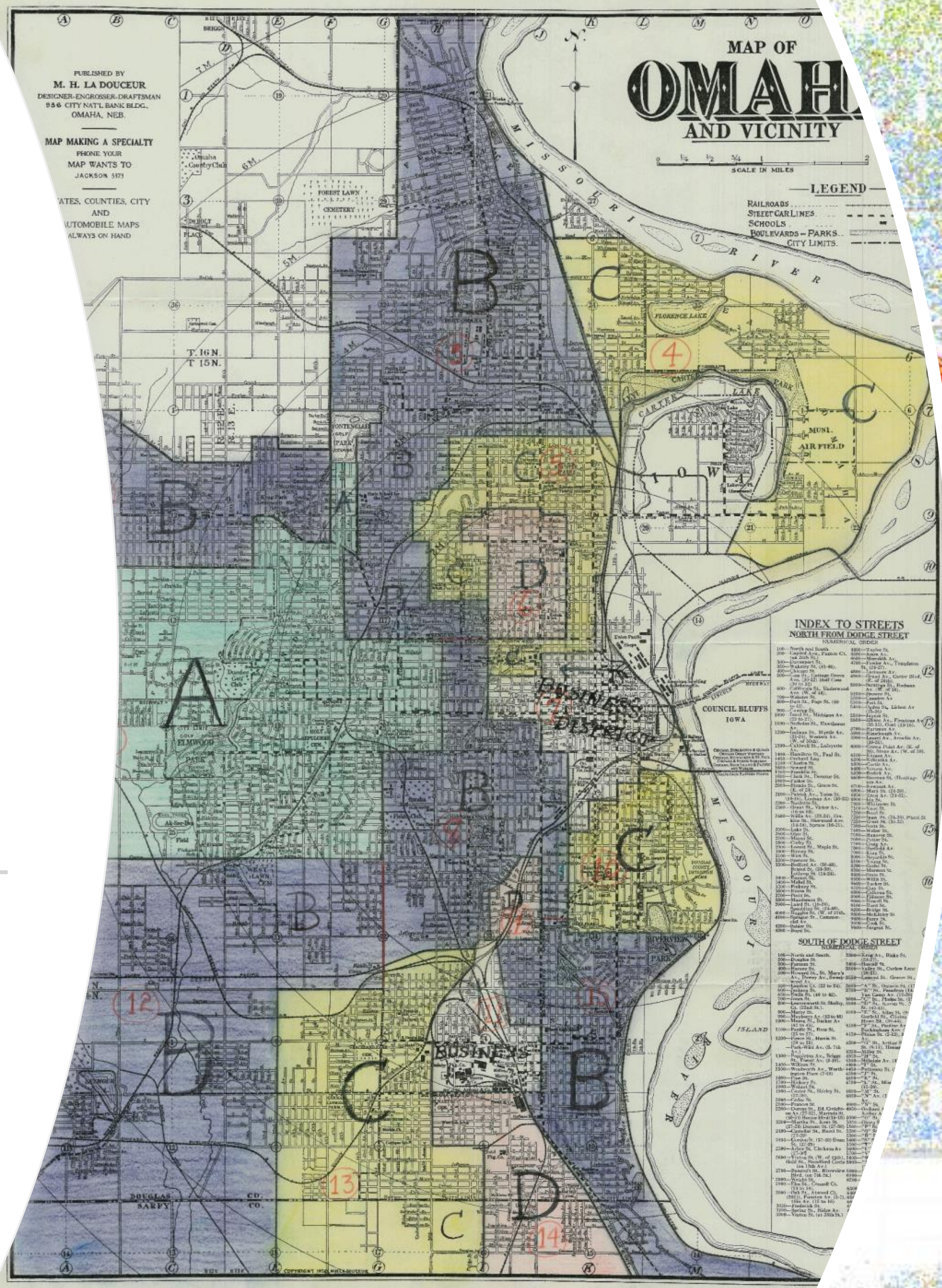
- **Homeowners Loan Corporation** (HOLC) program in the 1930s
- **Color-coded residential maps** were created for 239 cities
- Policy that **formalized racial and ethnic discrimination**
- Systematic denial of **mortgages**, **insurance loans**, and other **financial services**

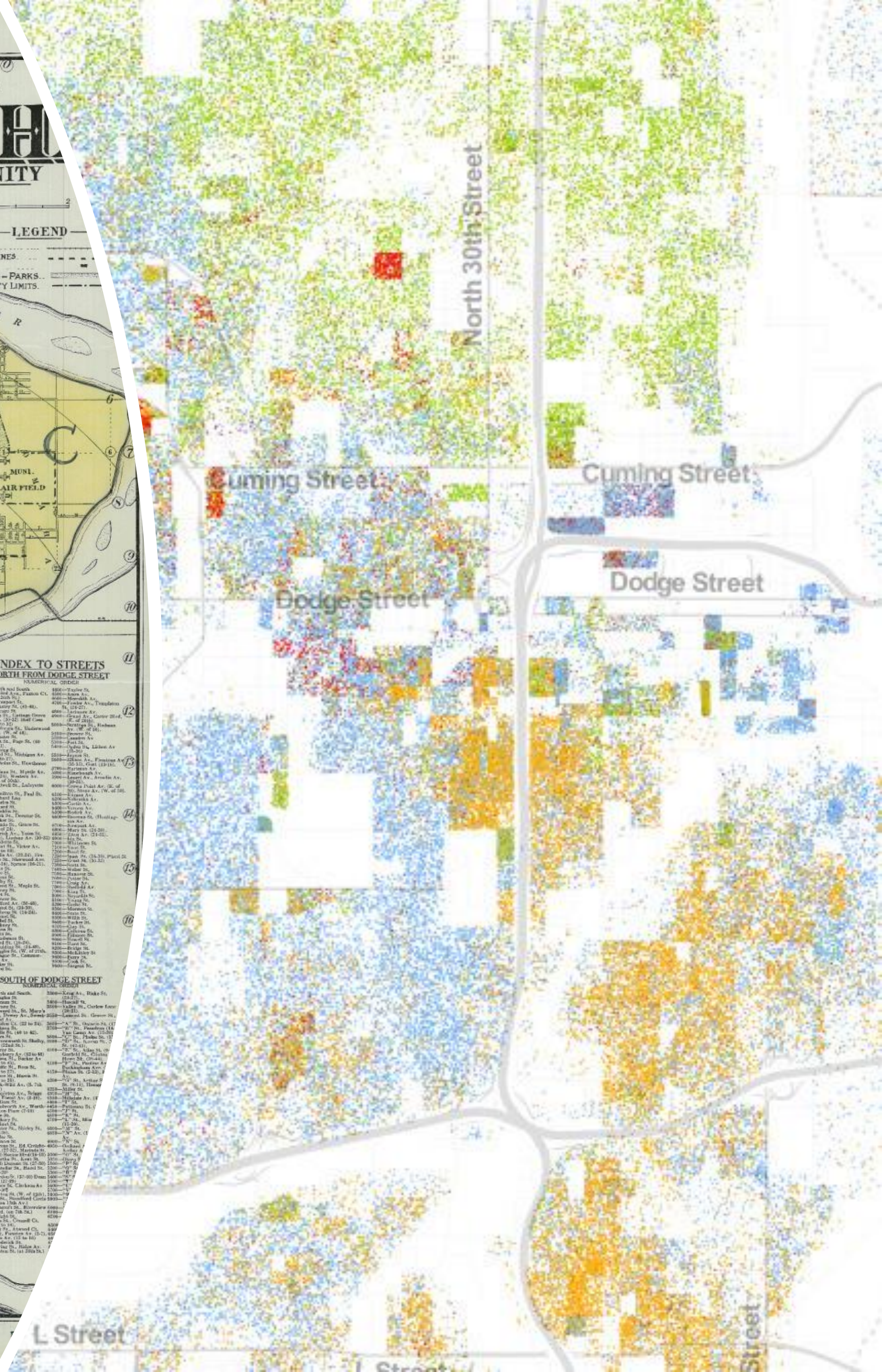
Omaha's "Redlining" Map (1935)





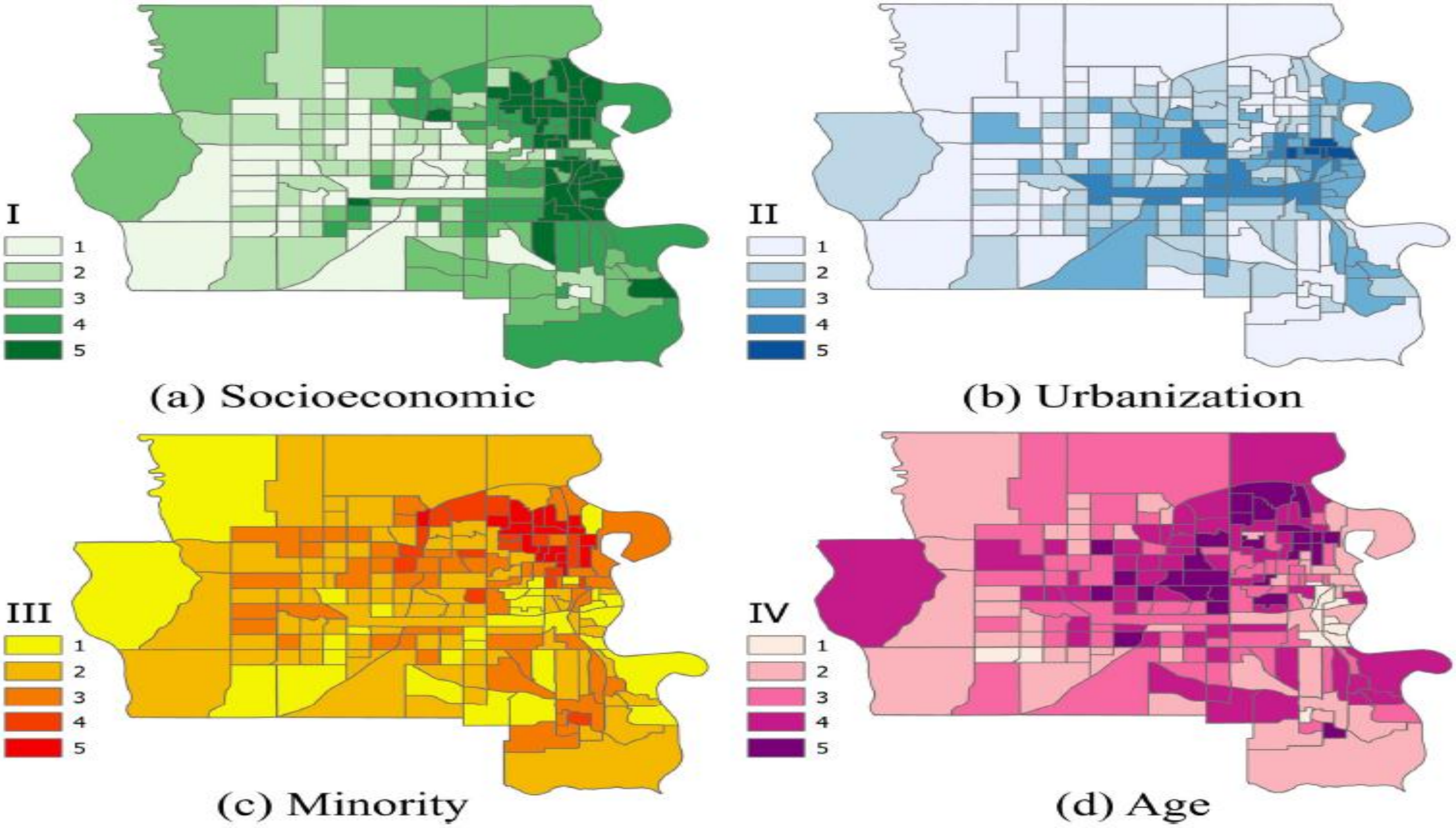
1935 & 2022





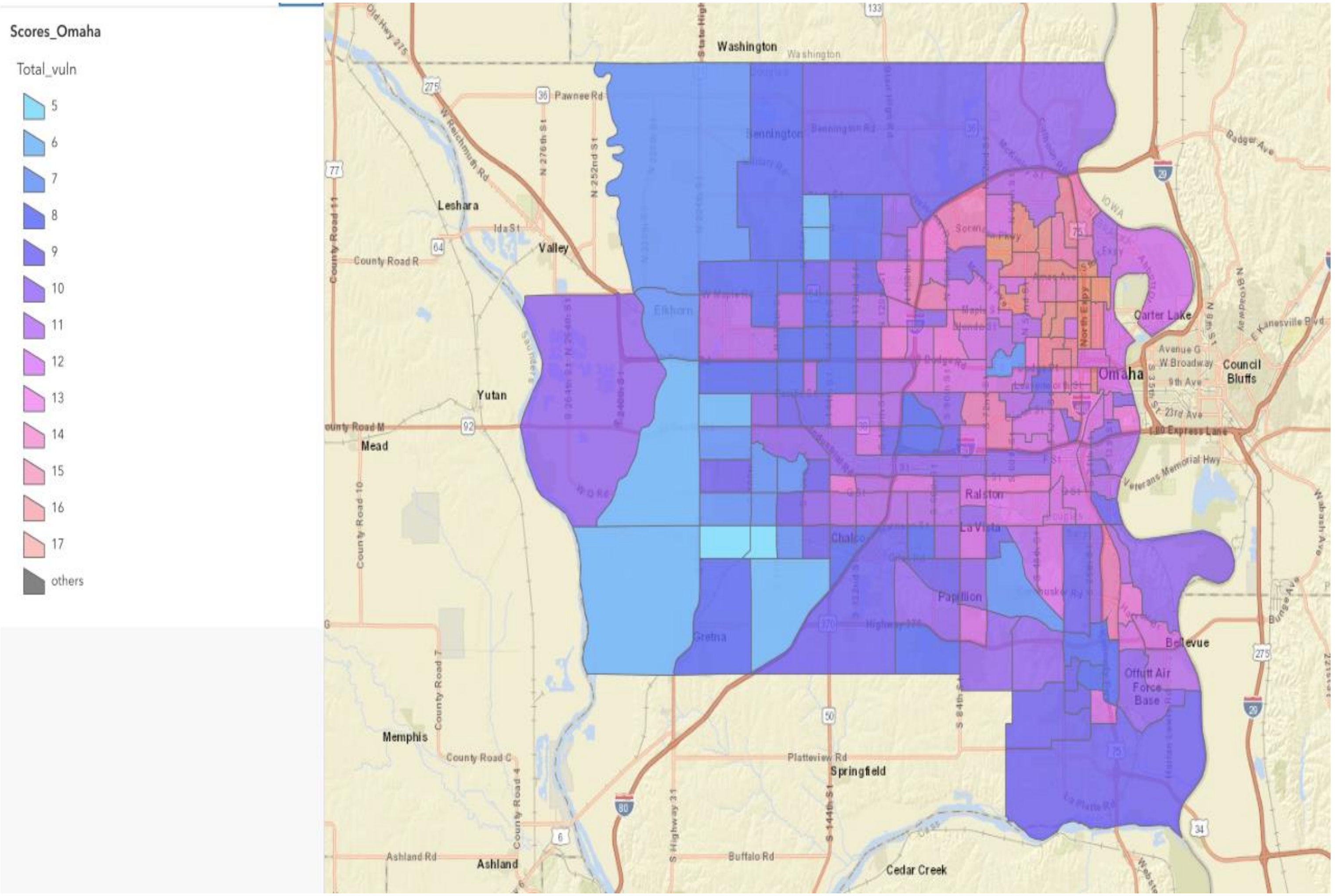
White: blue dots
African American: green dots
Latino: orange
All others: brown

Vulnerability Mappings of Omaha Urban Area



Ref: Fard et al, (2021): Mapping Heat Vulnerability Index Based on Different Urbanization Levels in Nebraska, USA

Heat Vulnerability Index



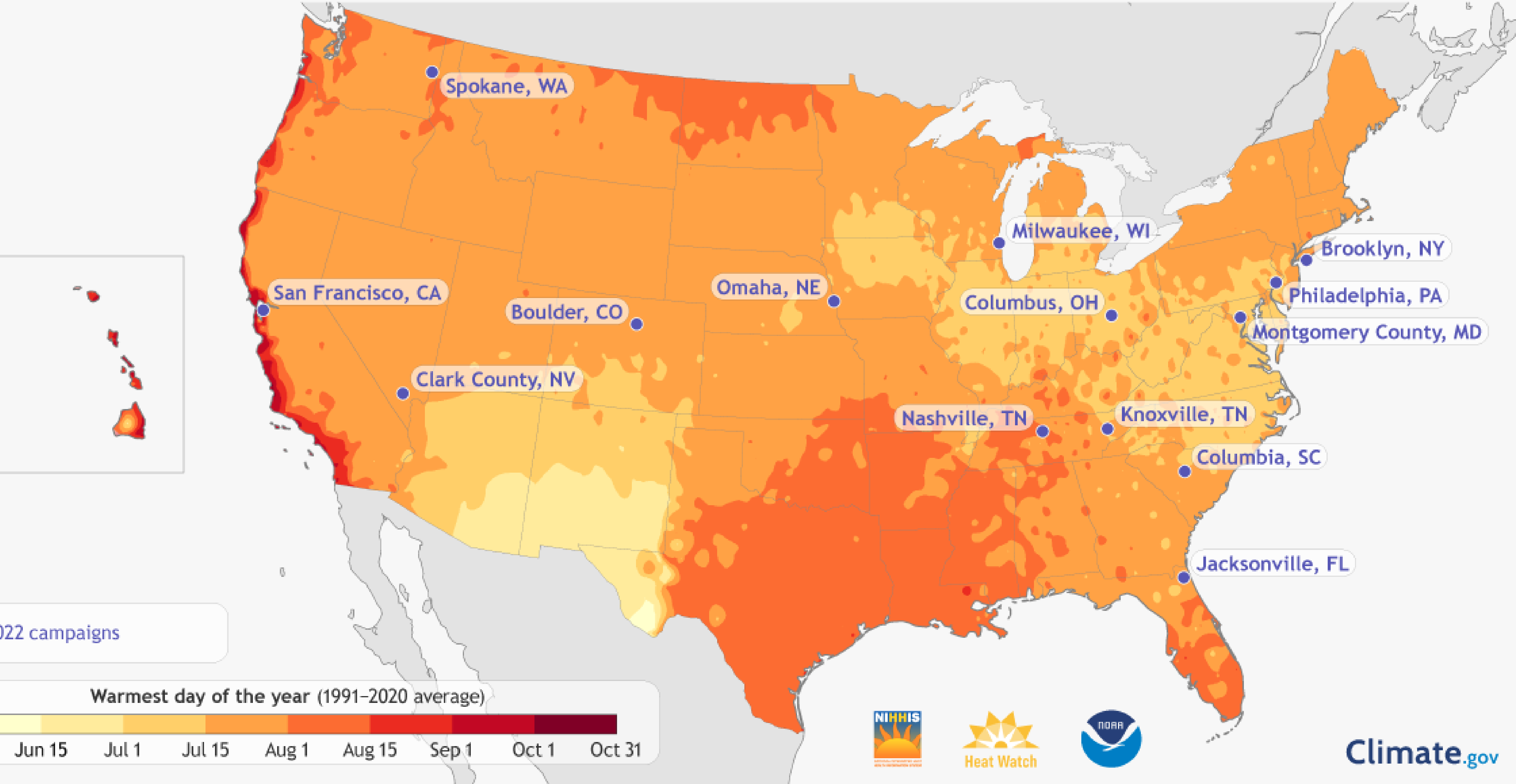
Study Aims

1. Determine the current distribution of heat in Omaha across historically segregated redlined and non-redlined neighborhoods

2. Investigate how the current heat distribution impact heat-related emergency department visits in Omaha

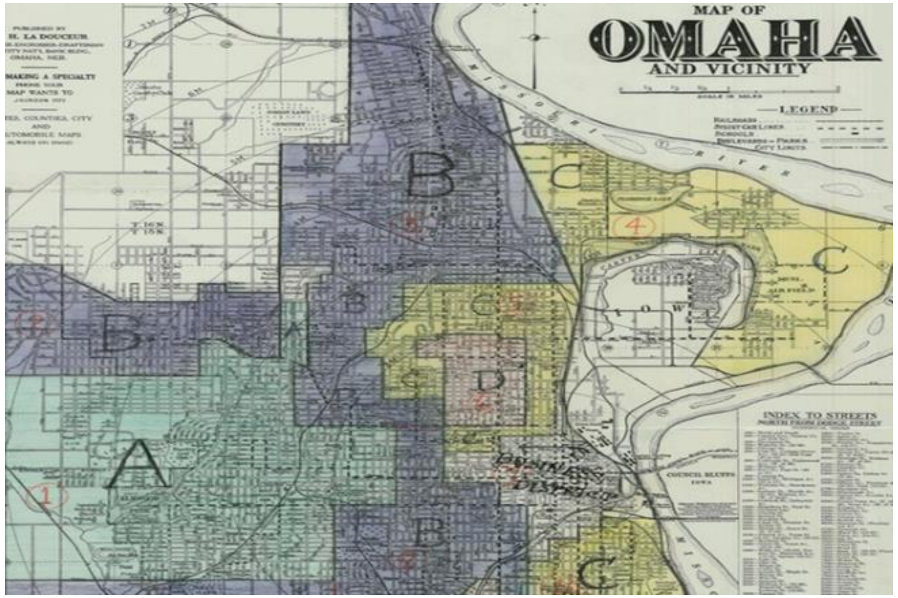
3. Assess Omaha residents’ attitude to risks, adaptation practices, and knowledge of heat waves

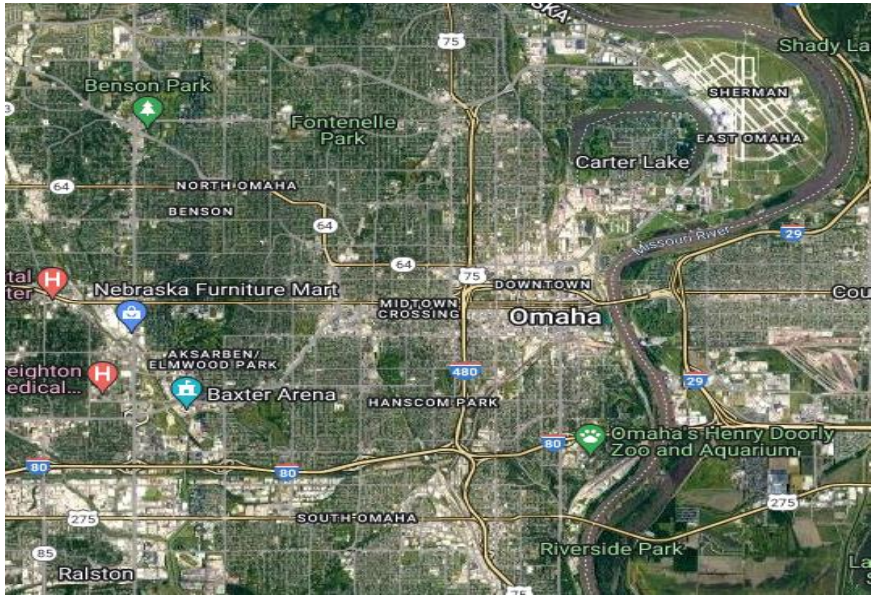
NOAA Urban Heat Island Mapping Campaigns: 2022 Locations

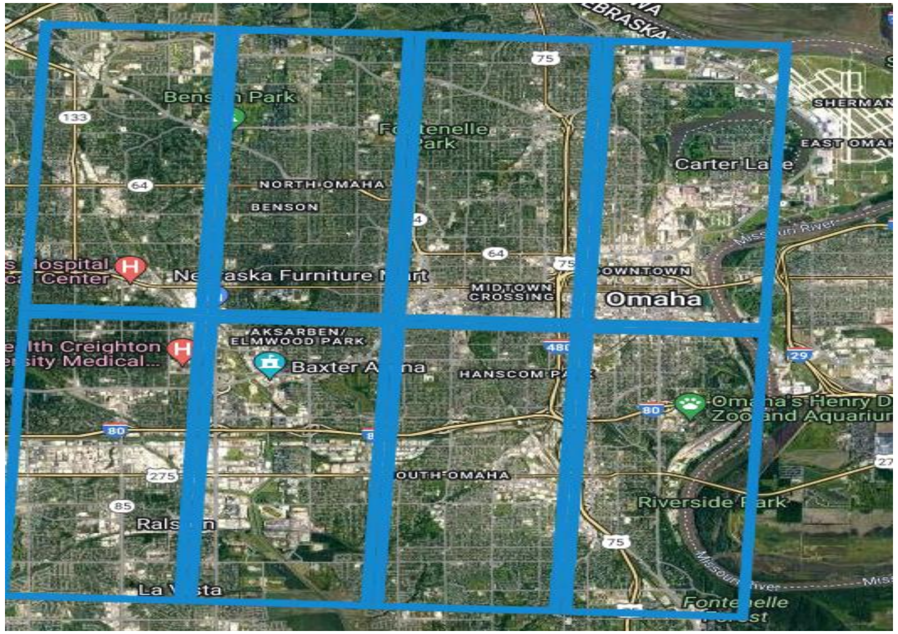


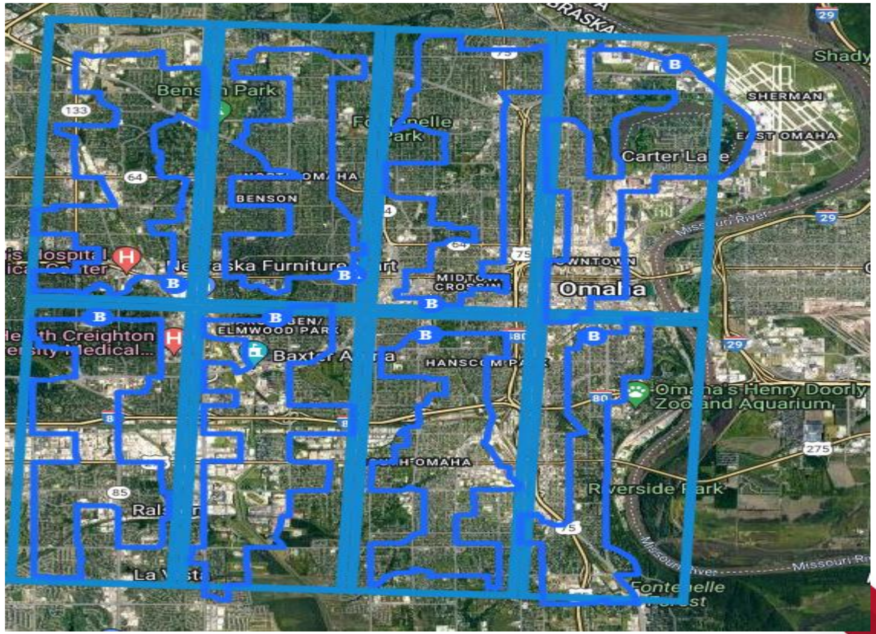
Community Outreach

Routes - Traverse









Campaign Day

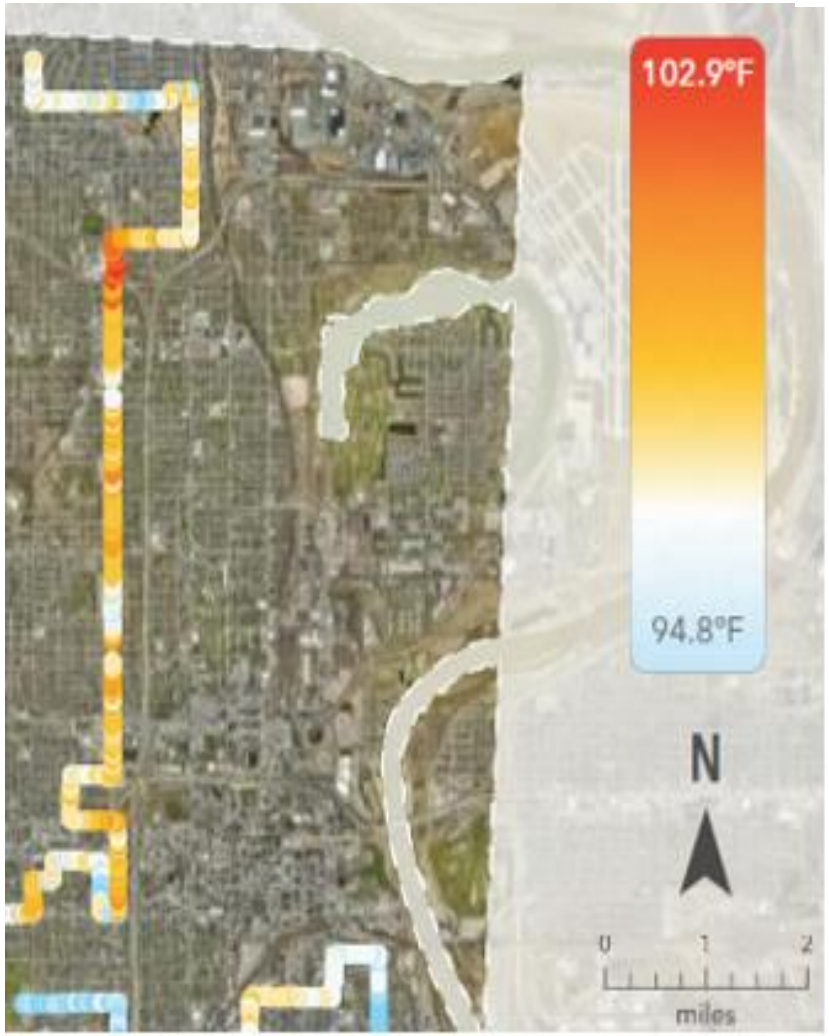
Campaign Outputs & Impacts

- 68 Volunteers
- 300 Estimated participants
- 8 Routes
- 43,714 Measurements
- 102.9° Max Temperature
- 9.4° Temperature Differential

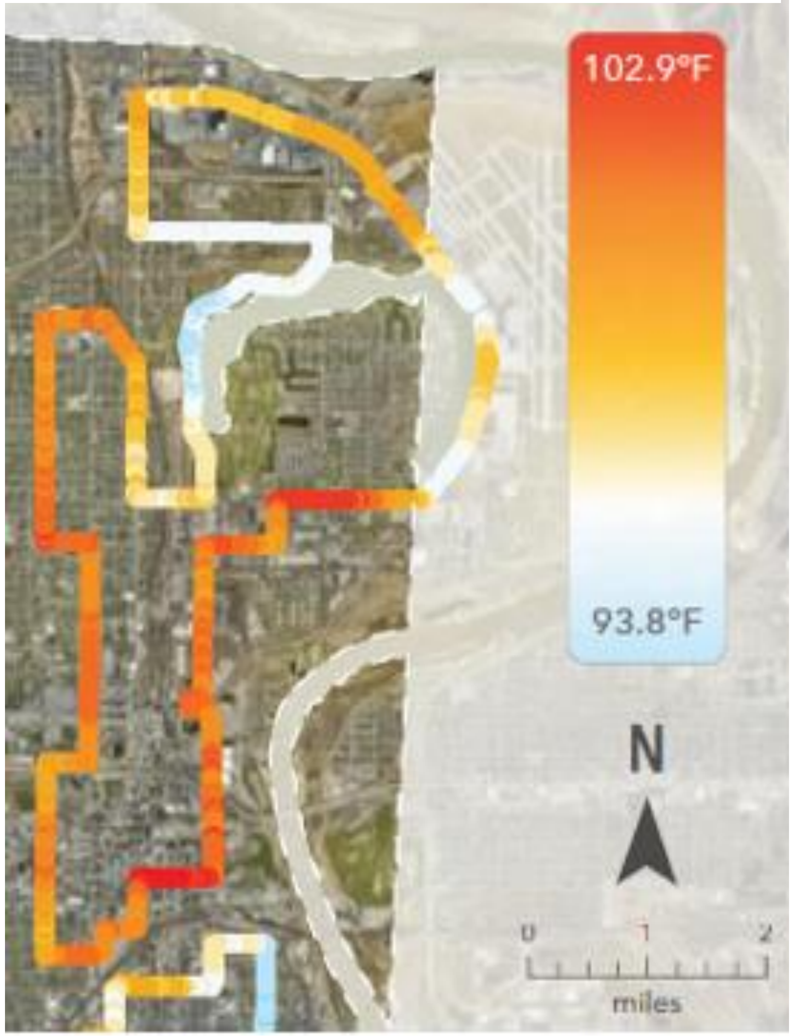
Traverse Points

Temperature (6 – 7 am)

Temperature (1 – 2 pm)

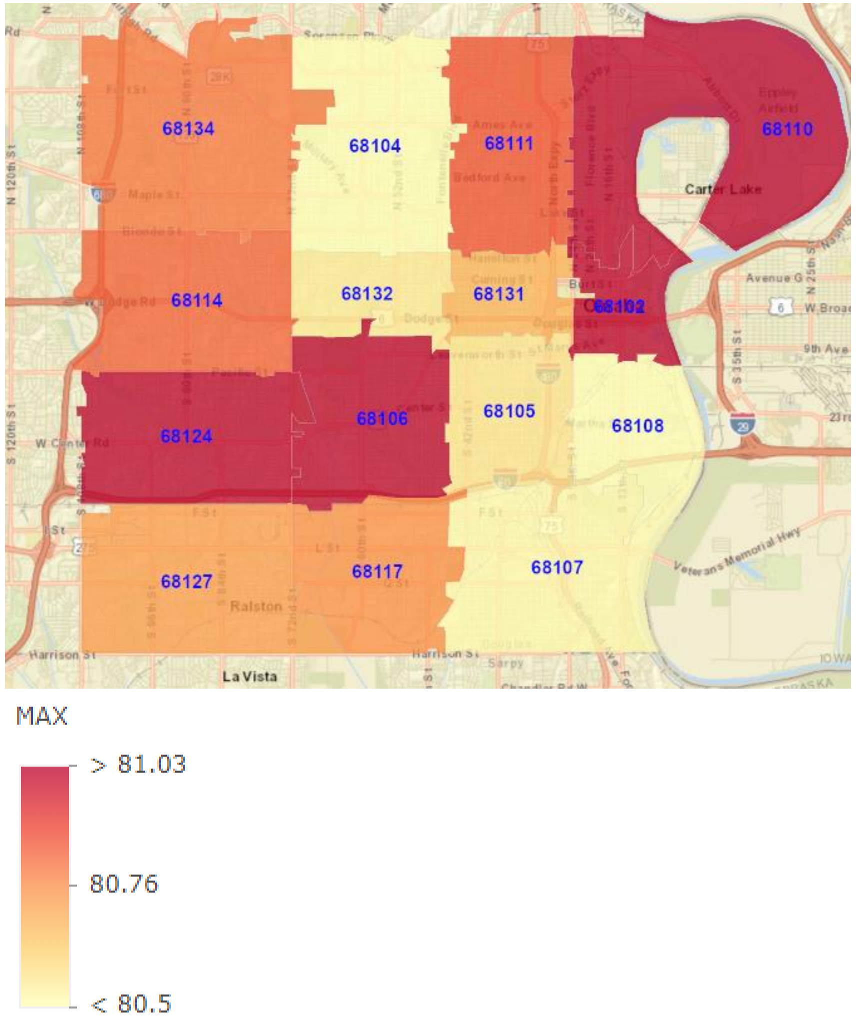


Temperature (7 – 8 pm)

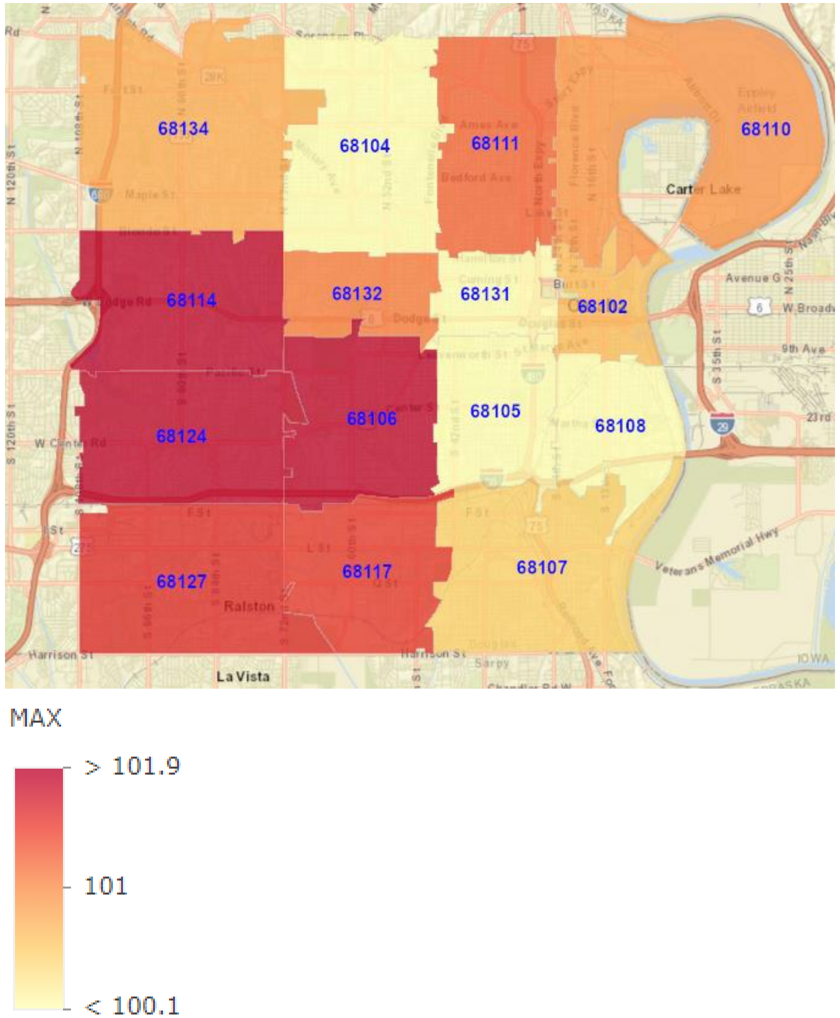


Zip Code Max Temperature

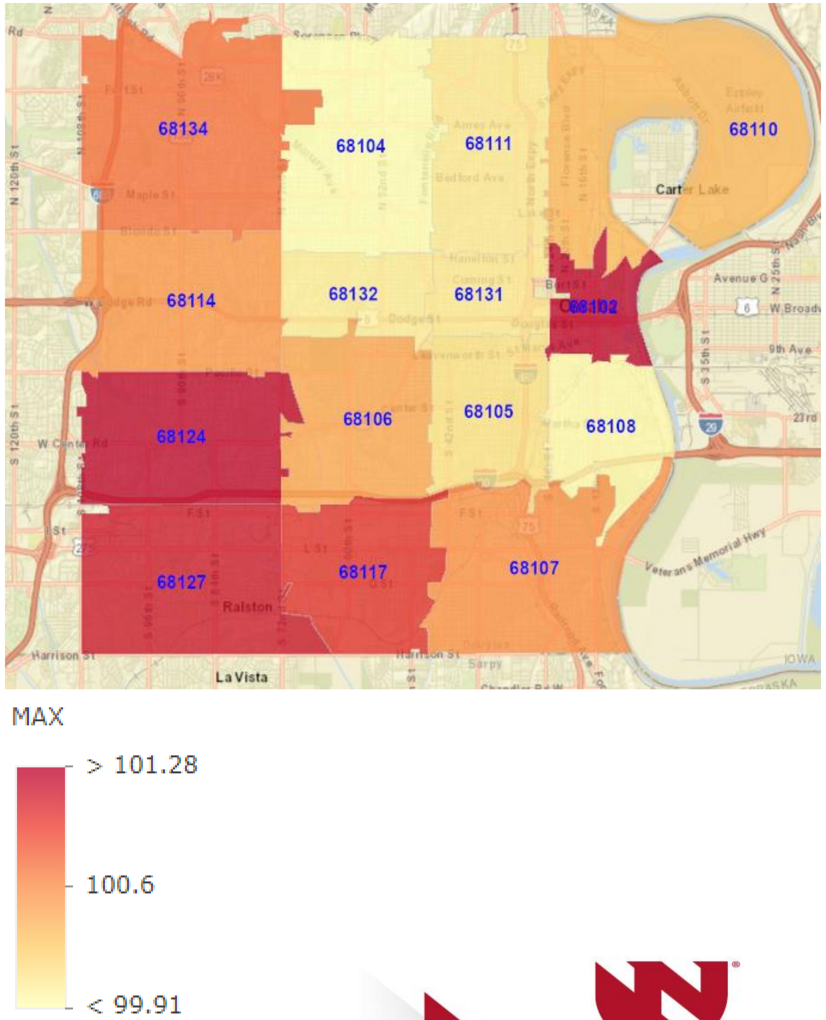
Temperature (6 – 7 am)



Temperature (1 – 2 pm)

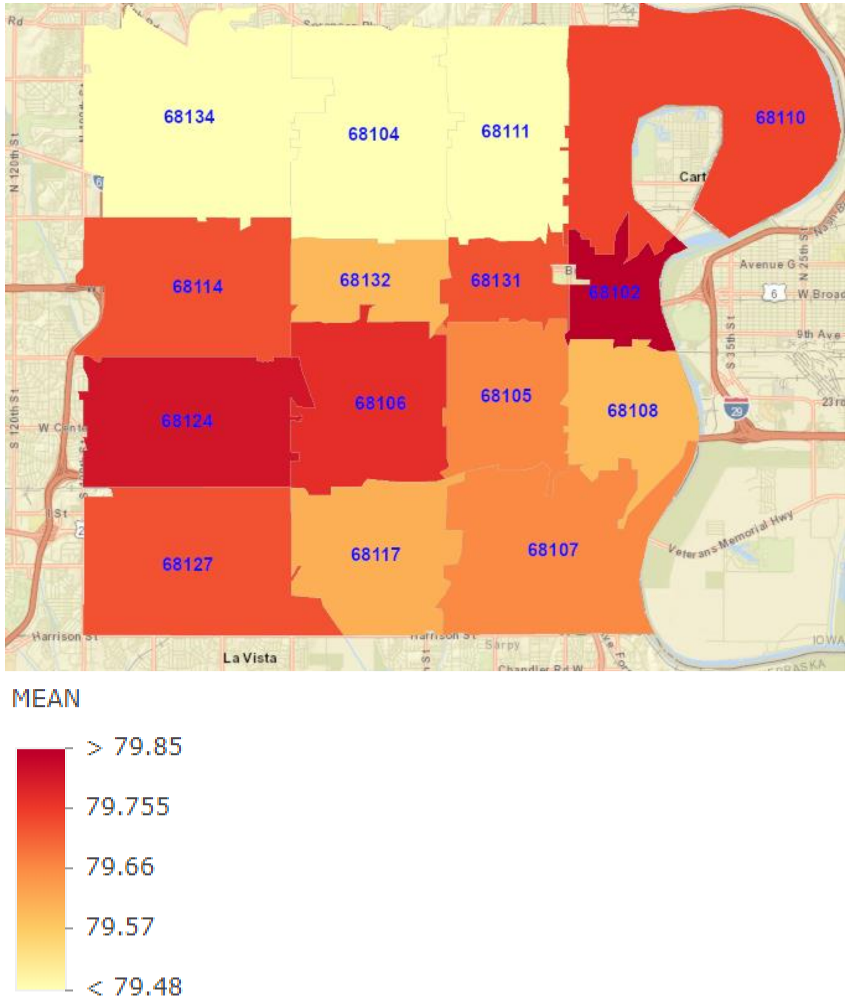


Temperature (7 – 8 pm)

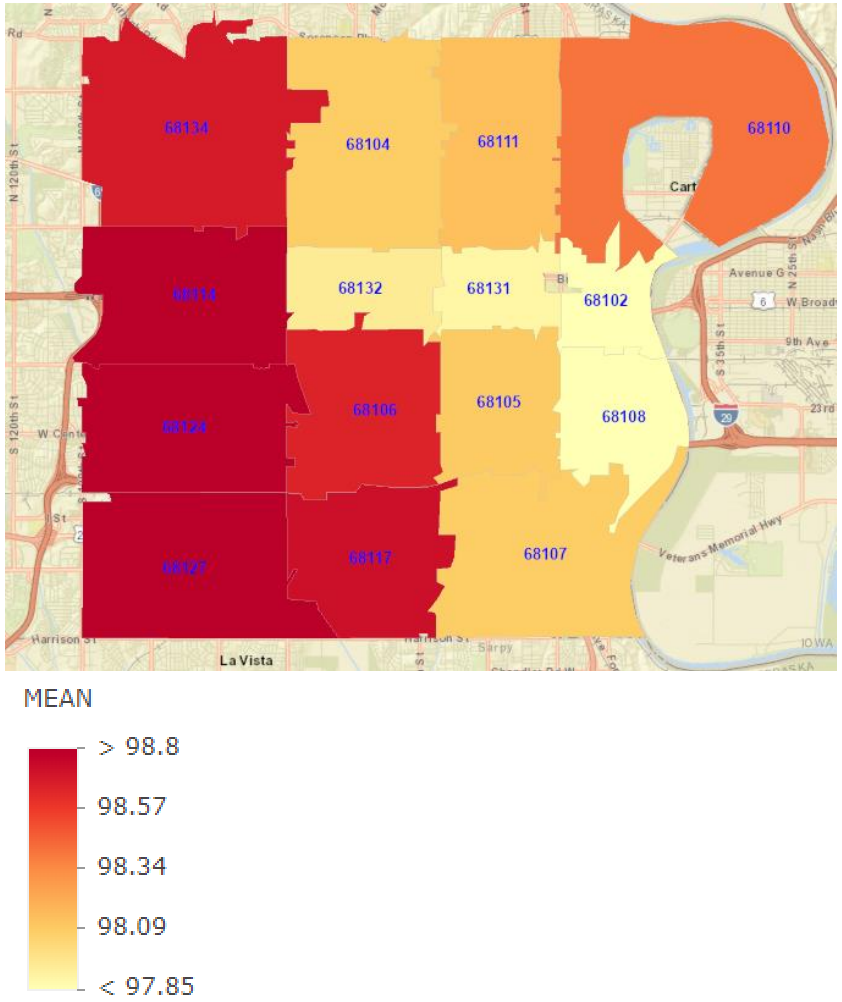


Zip code Average Temperature

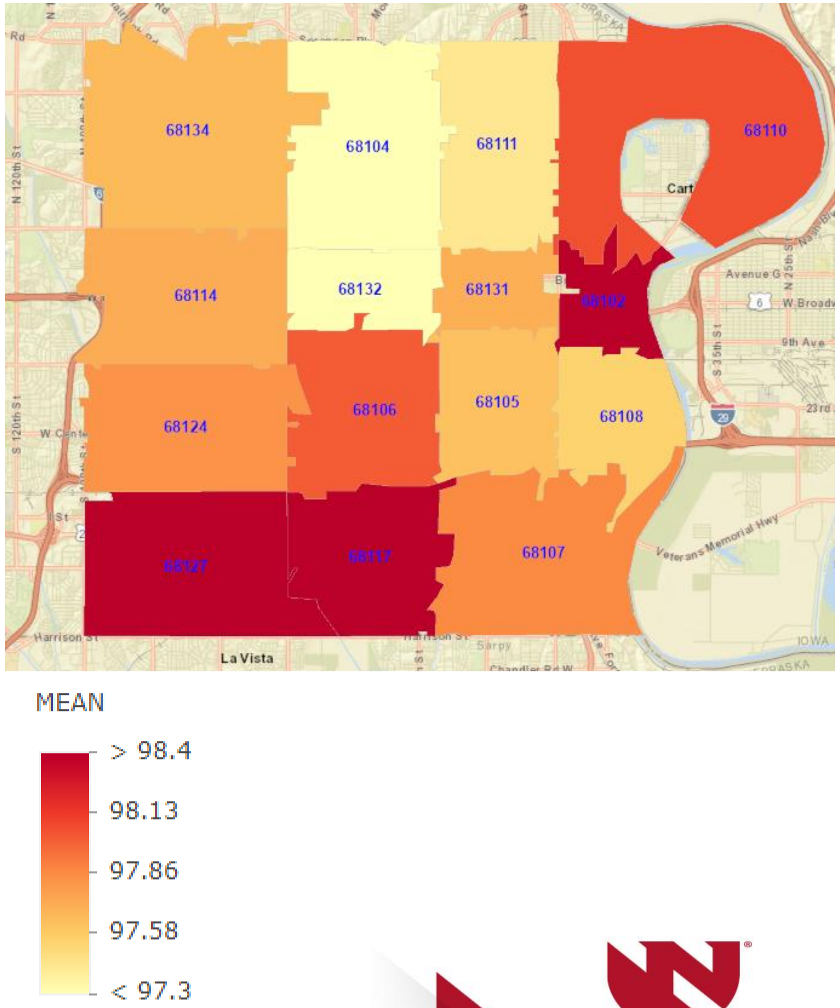
Temperature (6 – 7 am)



Temperature (1 – 2 pm)

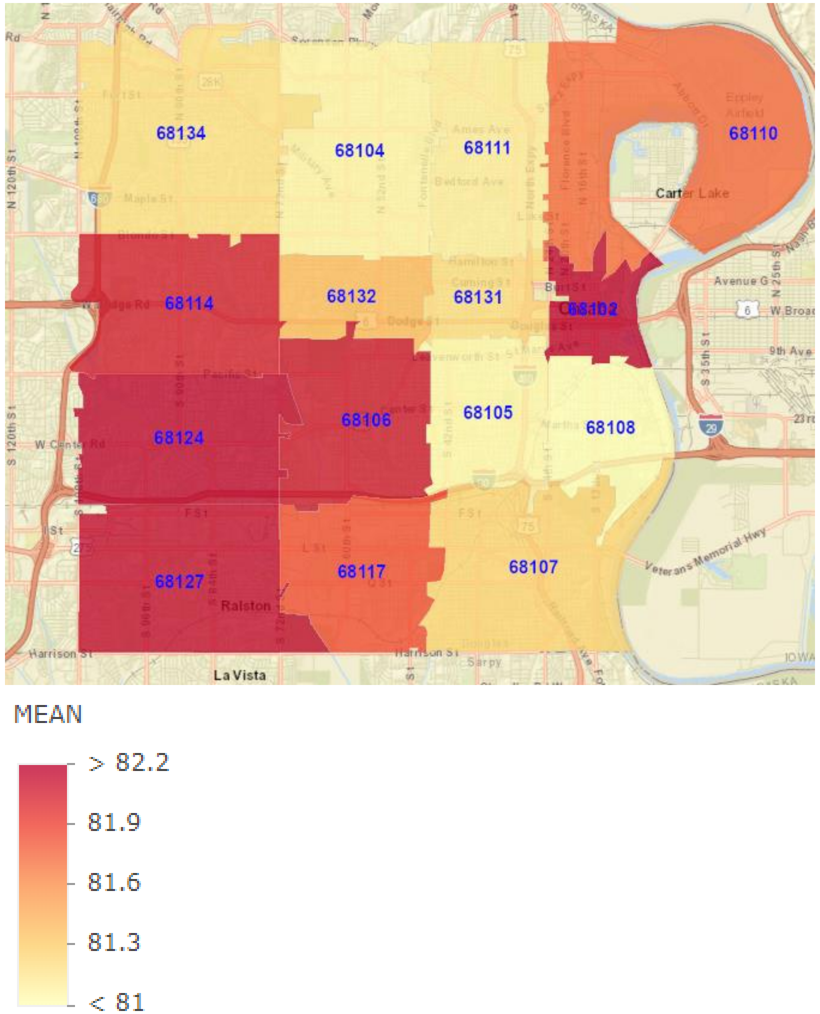


Temperature (7 – 8 pm)

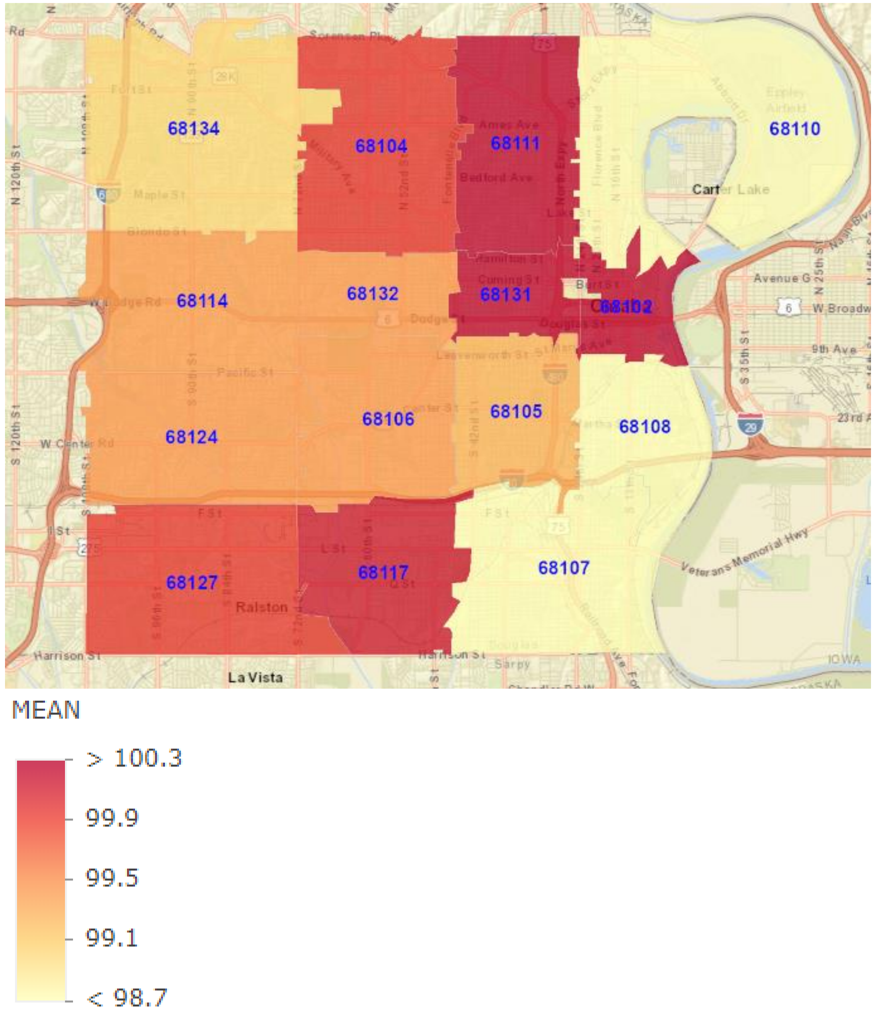


Zip Code Average Heat Index

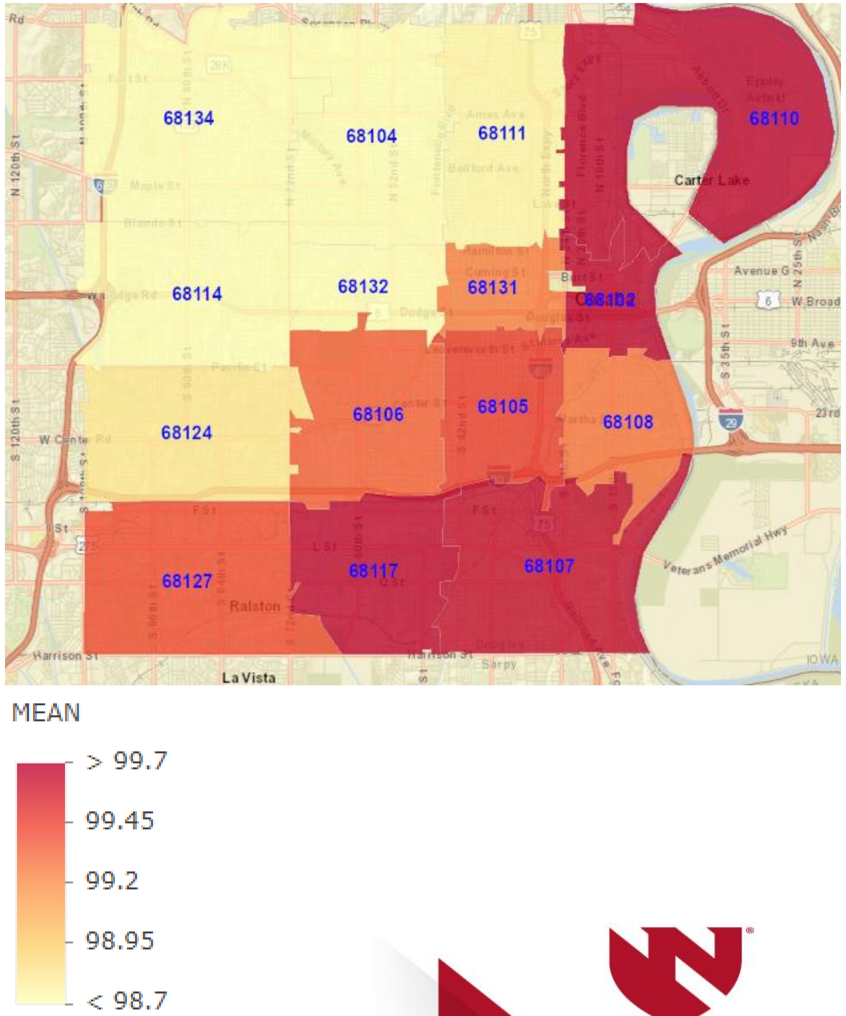
Heat Index (6 – 7 am)



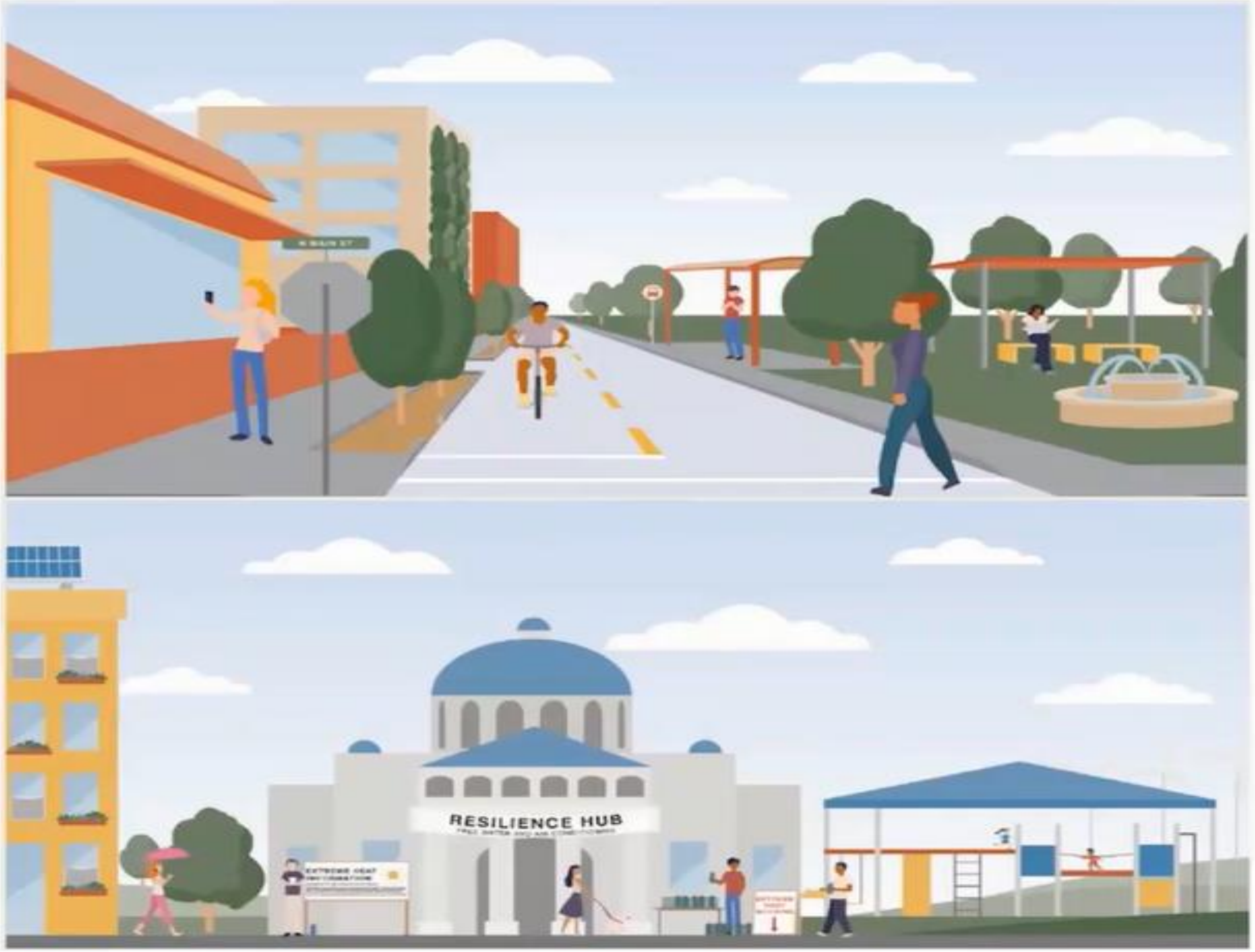
Heat Index (1 – 2 pm)



Heat Index (7 – 8 pm)



Next Steps

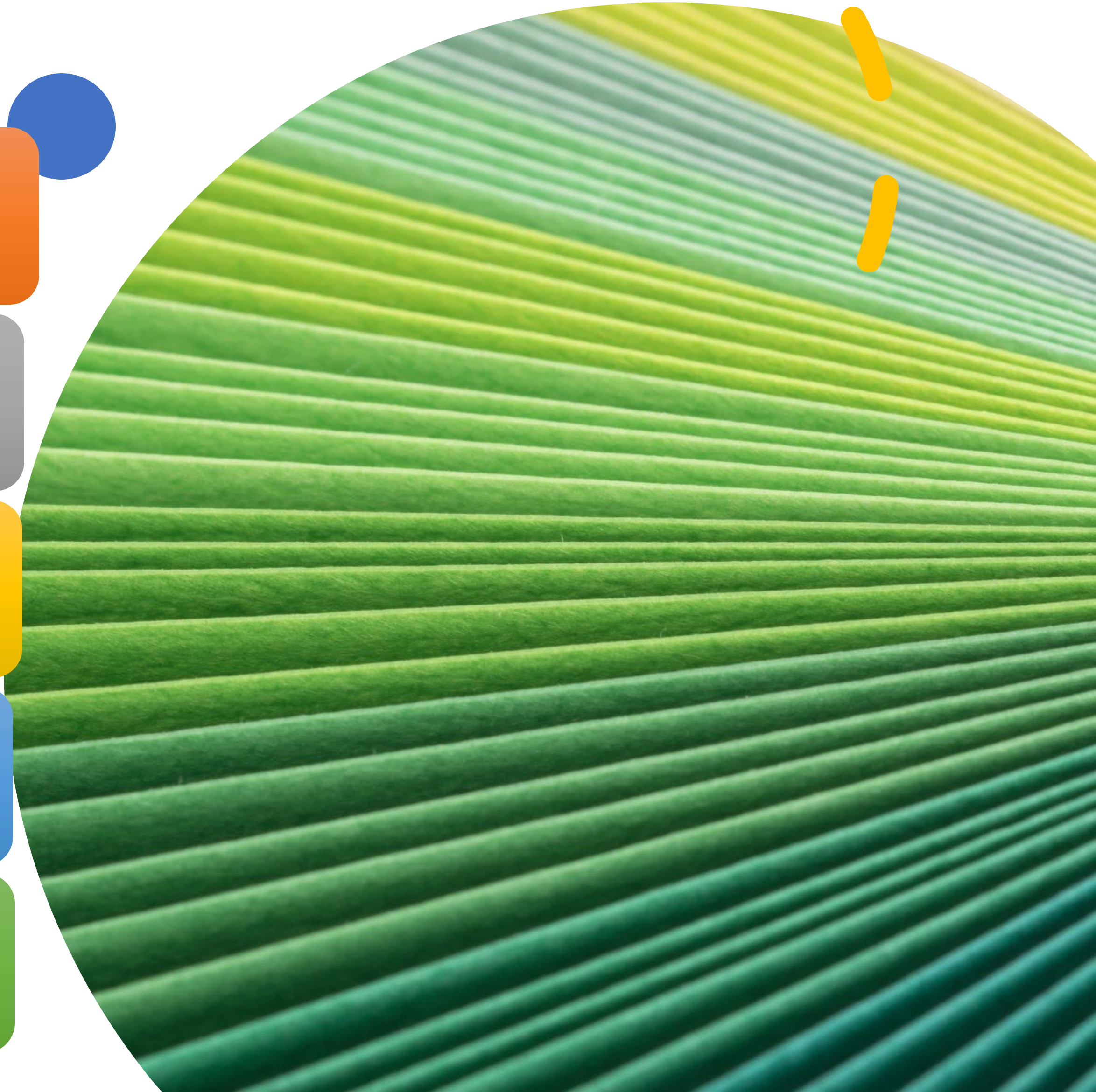


Solutions both **mitigate** & **manage** the risks associated with heat!

Meerow & Keith, 2022

Heat Resilience Workgroup

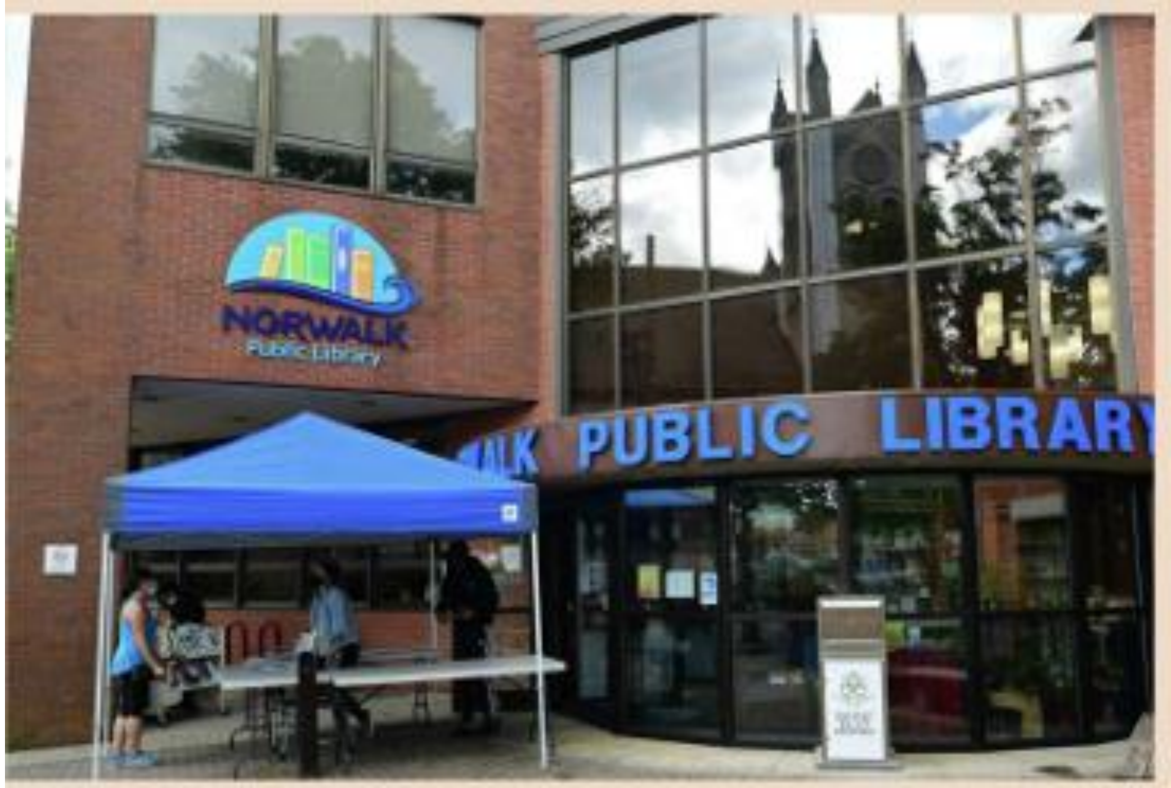
- Shared leadership
- Develop communication strategies and resources.
- Development of extreme heat preparedness plans
- Prioritize health equity into decision making.
- Tackle upstream drivers of health disparities and climate change.



Early Warming Systems

- Bi-directional education
- User-friendly tools
- Communicate timely and useable information
- Allows individuals to take action to reduce risk
- Prepare an effective response

Accessible Resilience Resources



Make cooling centers accessible and culturally sensitive.

Invest in urban parks and interactive water features.

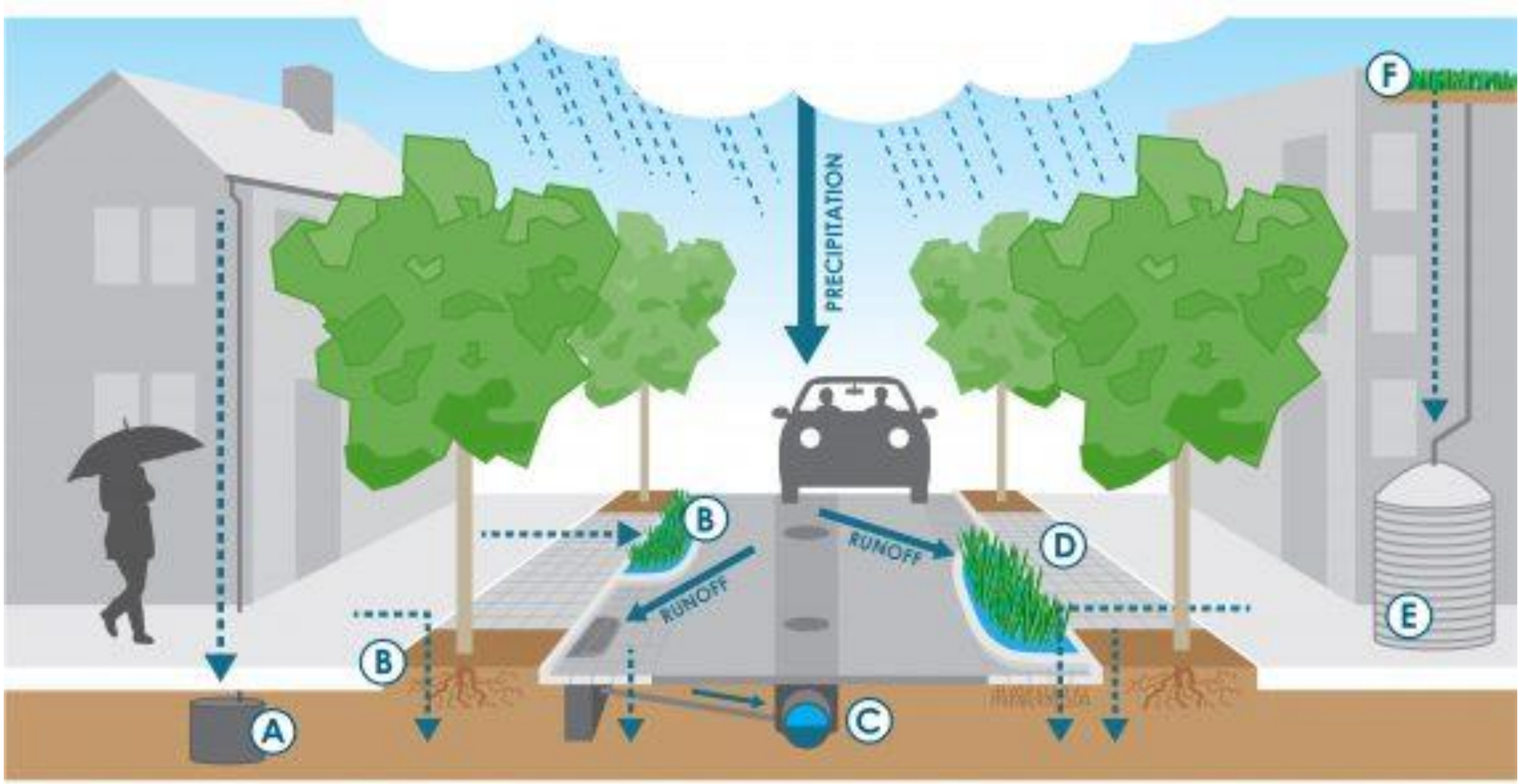
Adapt Land Use

Transform small areas into green spaces.

Convert recreational areas into greener spaces.

Invest in tree canopies along streets and in parks.

Integrated Resilience Assets



A: Dry Well B: Stormwater Planter C: Storm Drain D: Permeable Paving E: Rainwater Harvesting Cistern F: Green Roof

Bus Stop / Shade/ Cooling

Walkability / Shade / Linear Park

NIHHIS

The Claire M. Hubbard Foundation

National Weather Service

The Simple Foundation

NOAA

Douglas County Health Department

Youth Enjoy Science
Supported by the National Cancer Institute

CAPA

The Daugherty Water for Food Global Institute at the University of Nebraska

omaha City Planning

Keep Omaha Beautiful

Sierra Club Nebraska Chapter

One Omaha

Thank you