Measuring Extreme Heat Vulnerability in Los Angeles

By Aidan Cole

Context

- Climate change is expected to usher in increasing temperatures, increased precipitation/cases of drought, and increased rates of extreme heat events on a global scale (more temperature increase in last 50 years than last century)
- Climate researchers believe concurrent climate effects – increased rate of drought, wildfires and subsequent decline of green space – will drive extreme heat events to become more frequent and extensive
- Extreme heat is a multi-faceted issue, as it affects local and global economies, social contexts, public health, and environmental systems.

It's already hotter than it's supposed to be here, and only expected to get worse!

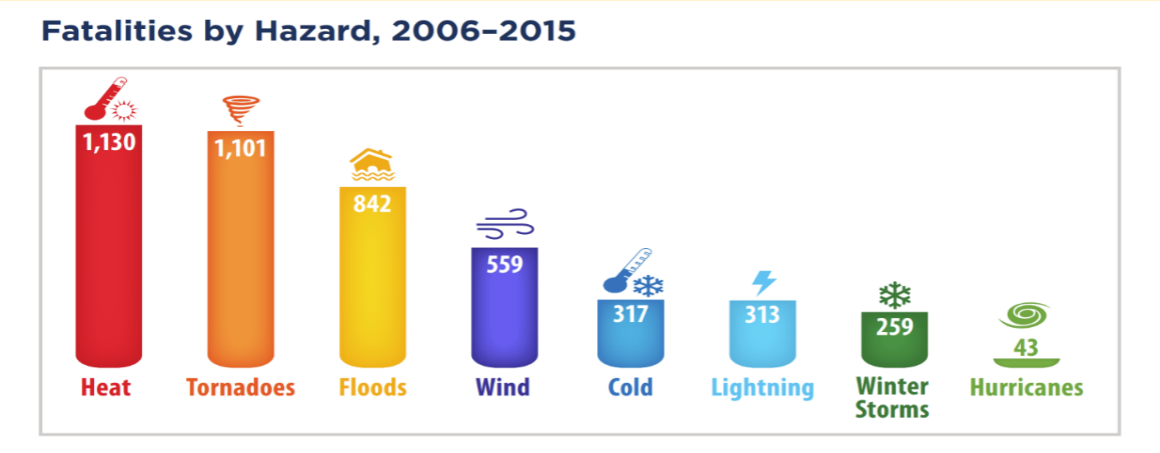
Los Angeles' Situation Pt. 1: Economy

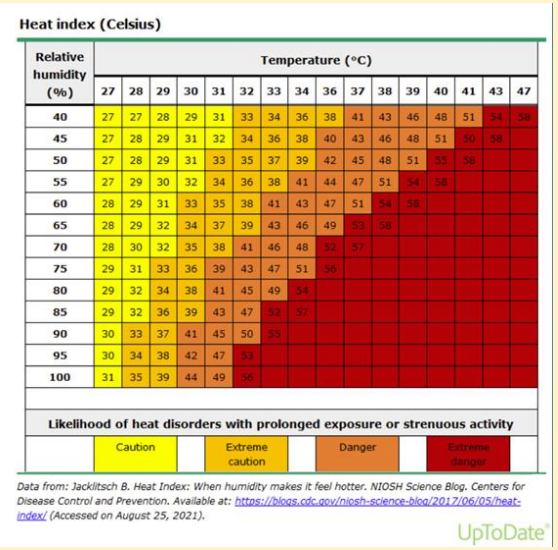
- Temperature rise in LA will match or even exceed global projections; increase of 2.7°F by 2050 and 5-9°F by 2100
- Productivity losses due to extreme heat cost the U.S. over $100 billion per year – with this figure expected to DOUBLE within 8 years
- Industry most affected by heat is agriculture, which employs 10% of the City's population; CA stands to lose too as leading state in the U.S. in terms of agriculture-derived income

- Economy currently reliant on Hollywood and tourism (41 million tourists/year = over $17 bil, +$50 bil/year from Industry)
  - As City becomes increasingly uninhabitable, unprecedented social and economic consequences

Los Angeles' Situation Pt. 2: Social

- LA's community "beat-the-heat" assets (i.e. hospitals, cooling centers, emergency preparedness sites, and public parks and pools) are disproportionately allocated across the City
  - Contributes to some areas being hotter or less apt to deal with extreme heat
  - Historically, the allocation of resources depends on relative affluence and racial composition of the area
- City demographic makeup is extremely diverse in terms of race, per capita income, education level, etc., and varies spatially. Thus...
- Extreme heat affects different populations in different ways
  - Costs associated with increased utility usage, installing heat-dissipating utilities, and hospitalizations/medical leave will exacerbate the underlying social preconditions of poverty; positive feedback loop
- Loss of jobs, involuntary relocation
  - Outdoor laborers (i.e. farmers, construction workers, etc) will be most affected
  - Car-reliant culture and lack of efficient public transit will make it harder to escape conditions and get assistance
- Human health risks and potential loss of life
  - Heat stroke, heat exhaustion, respiratory and cardiac dysfunction, renal disease, and death
  - Extreme heat is the most common natural disaster-related cause of death in the US and its death toll will only increase with climate change
  - 3,900 Angelino deaths were attributed to heat within the past 10 years, six times greater than expected

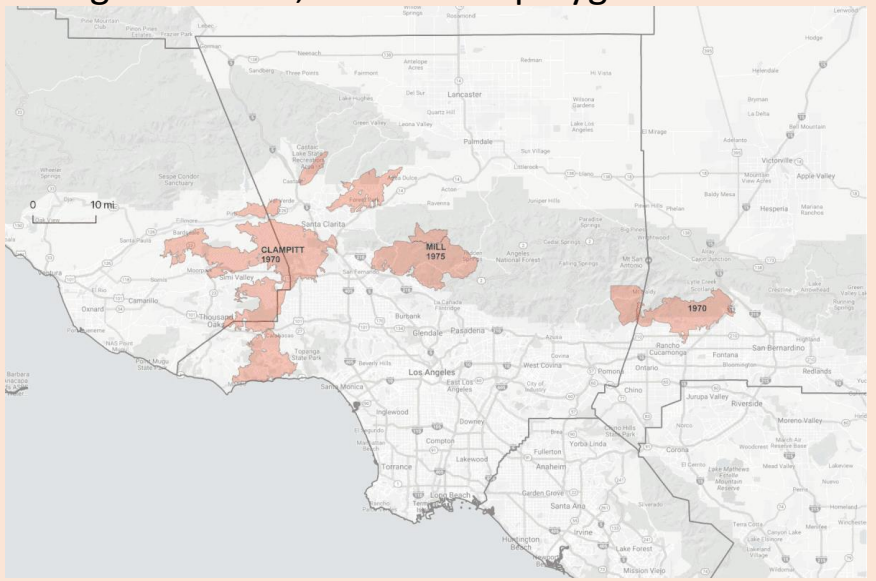




Los Angeles' Situation Pt 3: Environmental

- Percentage of tree canopy and publicly accessible green space contributes greatly to an area's resilience to extreme heat events
  - A majority of LA's area is urbanized; heat-absorbing impervious surfaces are prevalent
  - Preservation and maintenance of these areas is especially important, as poor environmental health can lead to droughts and wildfires
- Largest ecological assest that lies within the City's jurisdiction is the Los Angeles Forest
  - 700,000-acre reserve; backyard for 18+ million people in greater area, providing a plethora of important ecosystem services like heat dissipation, air purification, and species protection
  - Inhabited by a wide variety of plants and animals
  - Creates opportunities for aesthetic, cultural, educational, recreational and research use
    - As an Angelino, this area is very important to me

Los Angeles Forest, outlined in polygon boundaries



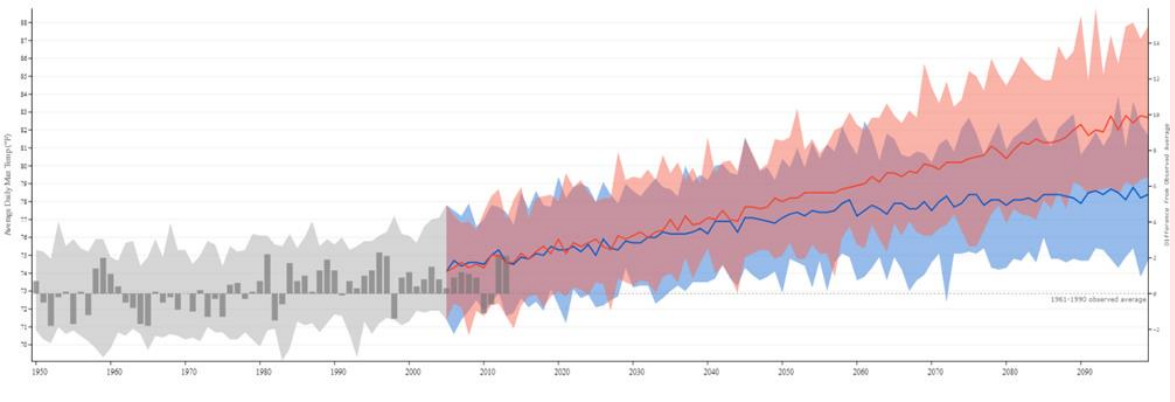
GIF of historical wildfires in Los Angeles, note relationship with green space

Converging Implications and Question

Issue:

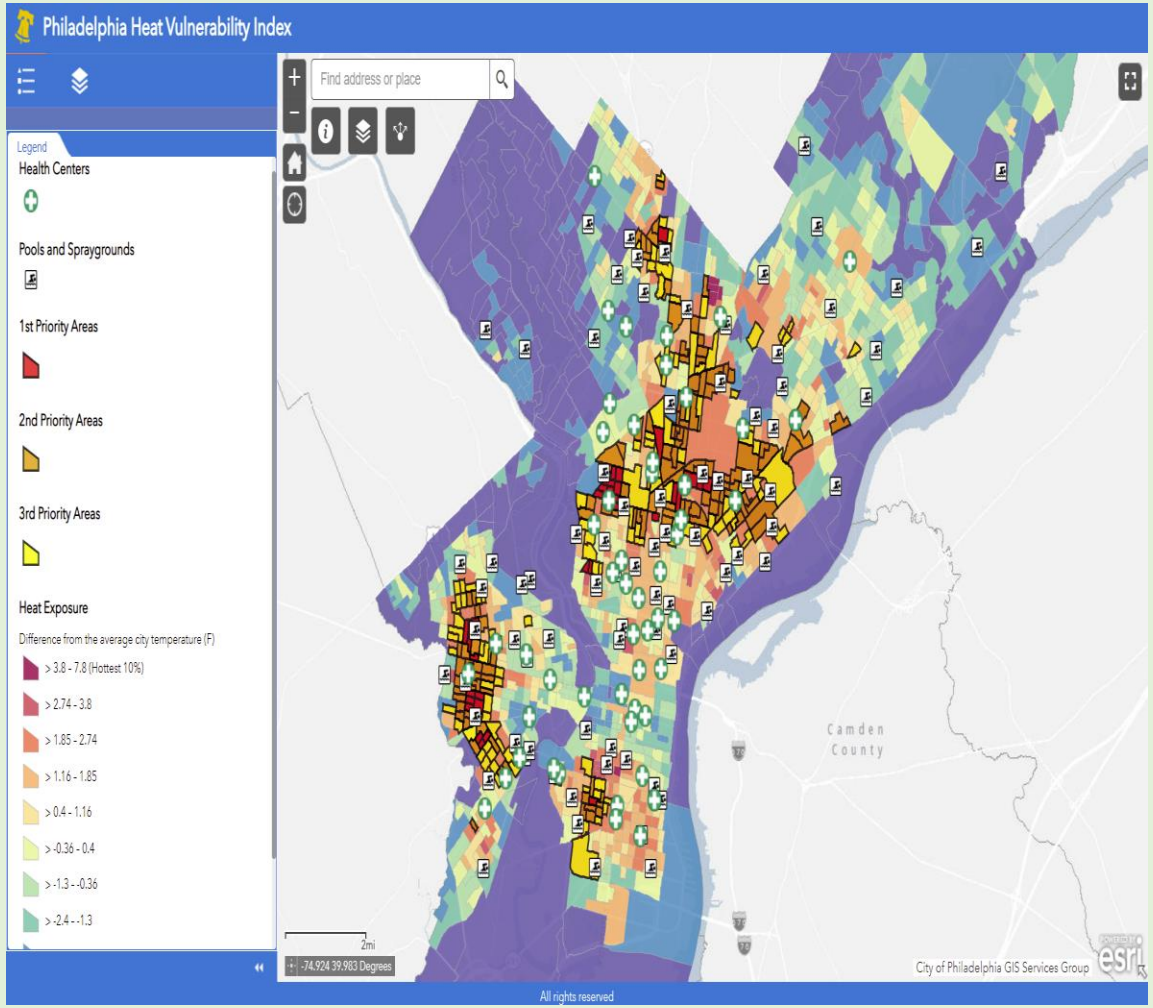
1. Extreme heat is a detriment to the economic, social, and environmental systems present within the city
2. The rate of extreme heat events is only projected to get worse in the future
3. Different populations and neighborhoods are affected differently depending on a number of factors, including: racial context, proximity to "beat-the-heat" resources, genetic predispositions, per capita income, etc.
4. City does not have many climate adaption strategies planned, or in-place, to help prevent or remediate damage

Question: "Which neighborhoods in Los Angeles County are disproportionately vulnerable to extreme heat?"



Red line denotes temperature increase without any mitigative or adaptive intervention (5-9 degree increase by 2100), blue line denotes temperature increase if City were to adhere to the strict IPCC “Global Warming of 1.5 °C” report (still going to increase by at least 3 degrees by 2100)

Project Idea



Philly's Heat Vulnerability Index ArcGIS interface, idea for map deliverable

Question (cont.): "Which neighborhoods in Los Angeles County are disproportionately vulnerable to extreme heat?"

Idea Conception: Inspired by Philly's Heat Vulnerability Index and U.S.C.'s Sea Level Vulnerability Study, which both calculate "vulnerability" in a holistic way

Deliverables:

1. Maps showing spatial arrangement of vulnerability that highlights most at-risk communities
2. Data-driven policy report informing the City of its most vulnerable areas to help optimize the allocation of possible climate-adaption strategies
3. Interactive story map to help bridge the divide between at-risk populations and community "beat-the-heat" resources

Method

Data:

1. Scrape census tract demographic data from American Community Survey API to assess neighborhood social health
2. Land-use and tree canopy data provided by Loyola Marymount University's Center for Urban Resilience
3. Public health and pollution data from CalEnviroScreen 4.0
4. Historic and current temperature and heat data from the California Heat Assessment Tool
5. Spatial features/proximity data (distance to nearest resource, count of each type of resource, Los Angeles Forest) using basic point and polygon data

Vulnerability Index Calculation: Create a model to calculate general neighborhood vulnerability (arbitrary range of values can then be classified into different vulnerability categories) using the factors listed above

Vulnerability Index Score Validation: Inform the decision to use/take-out/weigh certain feature coefficients based on features and findings included in the literature review

Method: Social Vulnerability

Social Vulnerability: the susceptibility of an individual or social group to the negative impacts of natural hazards and disasters due to characteristics that influence one's ability to prepare, respond, cope, or recover from a disaster (*FEMA*, 2020).

According to the Federal Emergency Management Agency's *Guide to Expanding Mitigation,* these are the populations who will be disproportionately affected by extreme heat:

- Underserved communities with a low socioeconomic status
- People of color
- Tribal and first nation communities
- Women
- Members of the LGBTQ+ community
- Individuals experiencing homelessness or displacement
- Populations over the age of 65 or under the age of 5
- Populations with limited English proficiency
- Service workers and migrant laborers
- Populations with limited cognitive or physical abilities
- Institutionalized populations, such as those in prisons and nursing homes, or individuals going through reentry
- Renters

Method: Social Vulnerability Cont.

The Center of Disease Control also has its own way of calculating Social Vulnerability in which it uses United States Census data to examine social vulnerability at the Census tract level for 15 social factors (broken up into four, weighted groups), including:

1) Socioeconomic status (0.25)

- Below poverty
- Unemployed
- Per capita income
- Educational attainment

2) Household Composition and Disability (0.25)

- 65 or older
- 17 or younger
- older than age 5 with disability
- single-parent households

3) Minority Status and Language (0.25)

- minority
- speaks English “less than well”

4) Housing Type and Transportation (0.25)

- multi-unit structures
- mobile homes
- crowding
- no vehicle
- group quarters/co-ops

Method: Social Vulnerability Cont.

Consolidating the features and methodology from the FEMA and CDC models, and based on Los Angeles' previously discussed unique context, I decided to use the following social factors, categories, and weights in my social vulnerability calculation (percentages -> quantiles :

1) Socioeconomic factors (0.2):
- Poverty
- Unemployment
- Educational attainment (over 25, w/o HS diploma)

2) Household Composition (0.2):
- Single-parent households
- Over 65
- Under 5
- Physical disabilities
- Mental disabilities

3) Minority Status (0.2):
- Non-white
- Immigrants
- Naturalized
- Limited English proficiency

4) Housing Status and Transportation (0.2):
- Homeless or displaced
- Institutionalized
- Lack of vehicle access or uses public transportation
- Low birth weight

5) Health Status (0.2):
- Asthma
- Cardiovascular disease
- Low birth weight

Note: Included the fifth, "Health Status," category to consider the public health effects of extreme heat

Method: Physical Vulnerability

Physical Vulnerability: the susceptibility of an area to the negative impacts of natural hazards and disasters due to characteristics that influence the environment's ability to prepare, respond, cope, or recover from a disaster.

Besides the physical vulnerability features that I outlined in **Method,** the City of Philadelphia's own Heat Vulnerability Index map includes several other features that contribute to a neighborhood's physical vulnerability, including:

- Difference between City average temperature and Census tract temperature
- Proximity to public pools, spraygrounds, and cooling centers
- Proximity to public schools (serve as neighborhood centers and assist in preparing for extreme heat events)
- Proximity to federally qualified health centers
- Air-conditioning prevalence
- Air quality

Using these variables as my initial physical vulnerability framework, I made a new model to calculate Physical Vulnerability, including the following factors:

- % green space
- Existing vs. Potential % tree canopy coverage
- Nearest feature (per type of resource)
- Count of features (per type of resource)
- PM 2.5 concentration
- Ozone concentration
- Projected vs. Historical surface temperatures
- Projected vs. Historical count and duration of heat events

"Beat-the-heat" resources:
1. Emergency preparedness (public schools)
2. Hospitals and urgent cares
3. Public pools and spraygrounds
4. Cooling centers (public libraries)
5. Public parks and green space

Method: Overall Heat Vulnerability Index

1. In order to standardize the data amongst features (ex. Units of percent, degrees Fahrenheit, feet), I attributed a quantile score to each feature within both the Social and Physical Vulnerability models
2. Next, I calculated each tract's Social and Physical Vulnerabilities using the aforementioned models
3. Then, I simply added the two scores together and divided by the number of features (2) to get my Overall Heat Vulnerability Index

Results: Census Features

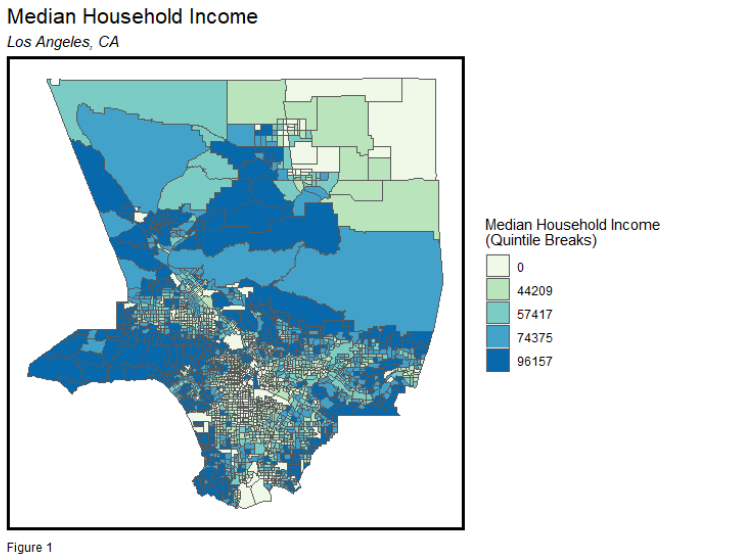


Figure 1

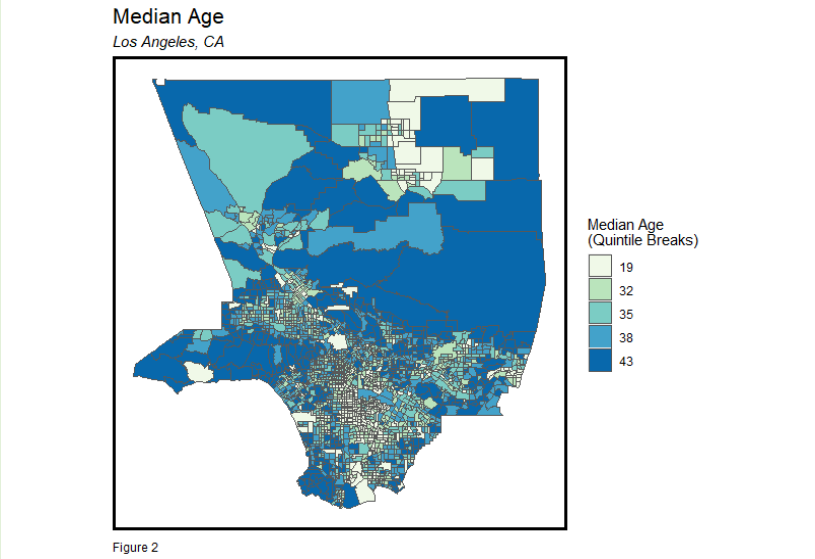


Figure 2

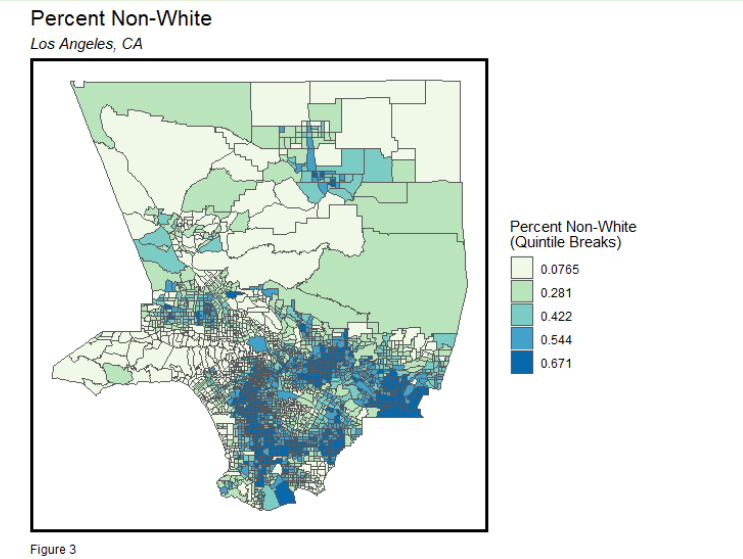


Figure 3

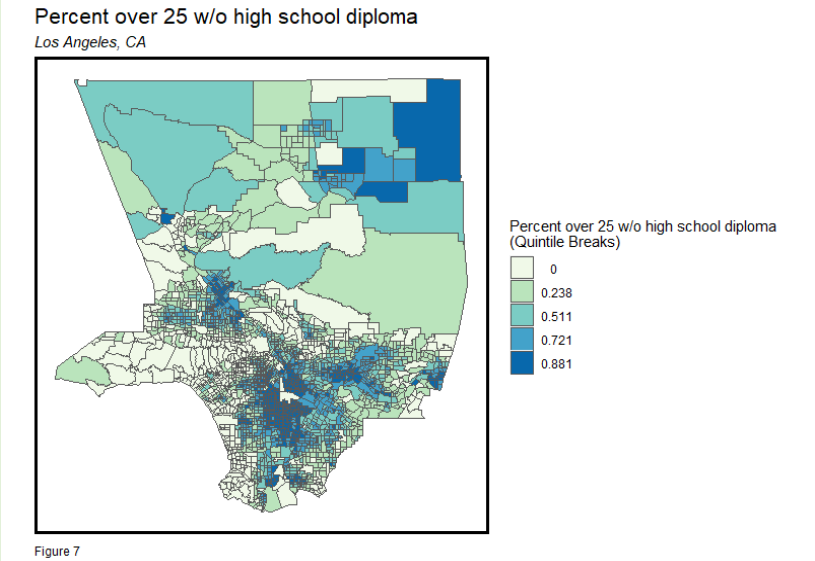


Figure 7

In general, older, whiter, and more affluent individuals are seen in the areas closest to the coast; as you move inland towards Downtown and the San Fernando Valley, the population gets more comprised of younger, non-white, and less educated individuals

Results: Census Features

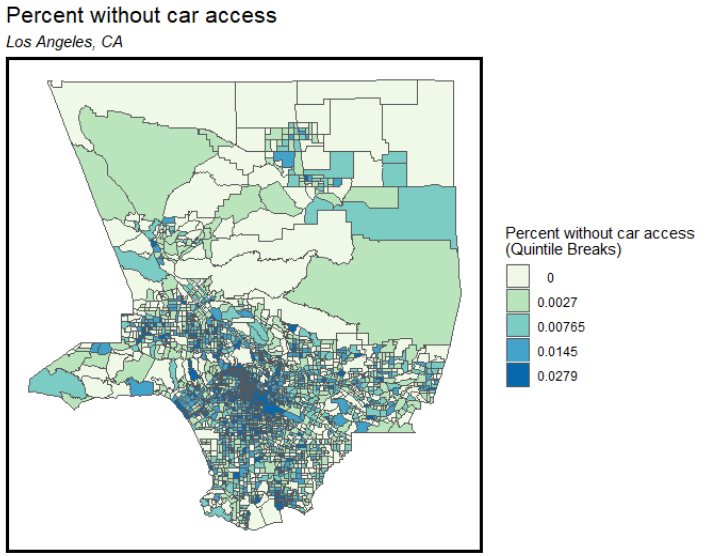


Figure 6

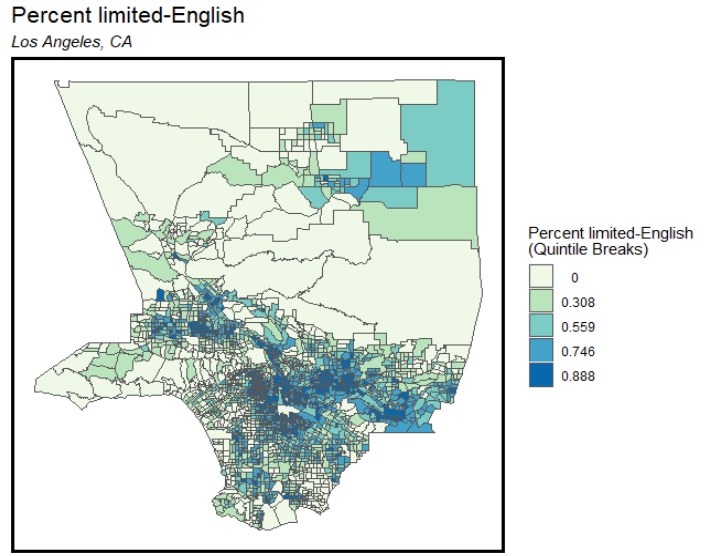


Figure 8

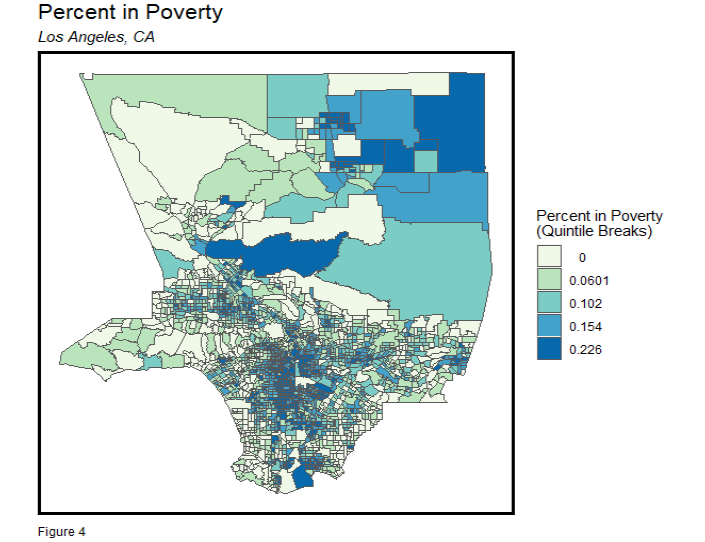


Figure 4

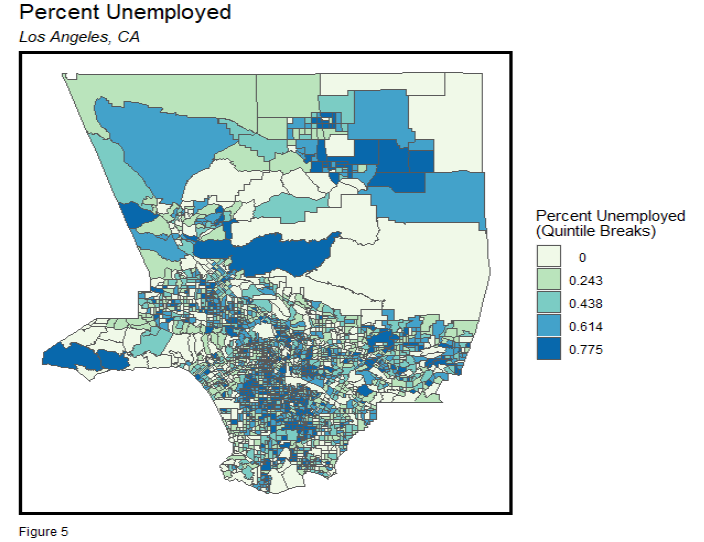


Figure 5

You can continue to see this trend in these additional features, with people living close to Downtown generally exhibiting high social vulnerability and people living close to the coast exhibiting the opposite. Note that there is high unemployment in Malibu, probably a result of retired individuals not filling out their Census information correctly or trust fund kids not having to work

Results: Resource Features

Cooling Center Locations

Los Angeles, CA

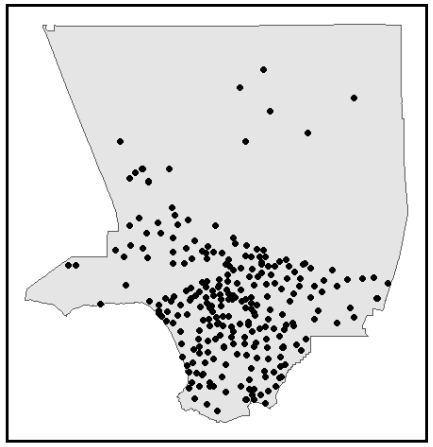


Figure 12

Emergency Preparedness Locations

Los Angeles, CA

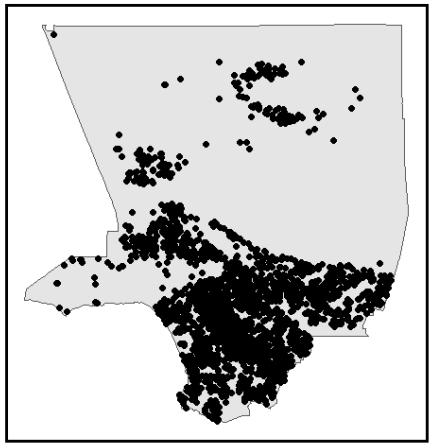


Figure 10

Note the spatial allocation of these important community "beat-the-heat" resources and their relationship to the Census features previously presented

Hospitals and Urgent Care Locations

Los Angeles, CA

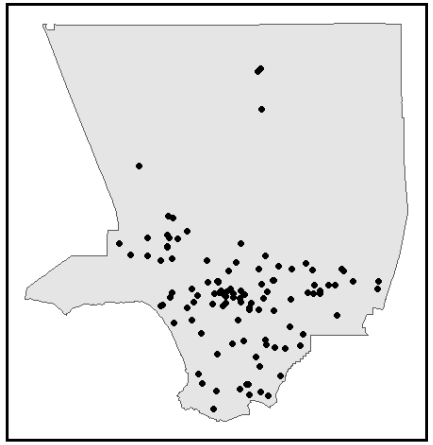


Figure 9

Public Parks and Green Space Locations

Los Angeles, CA

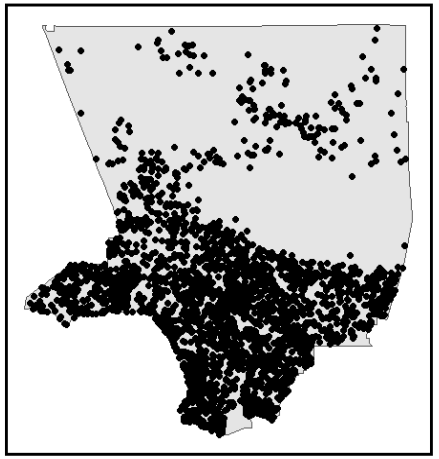


Figure 13

Public Pools and Sprayground Locations

Los Angeles, CA

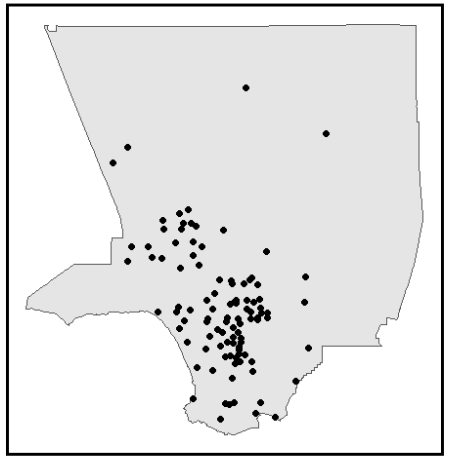


Figure 11

Results: Temperature Features

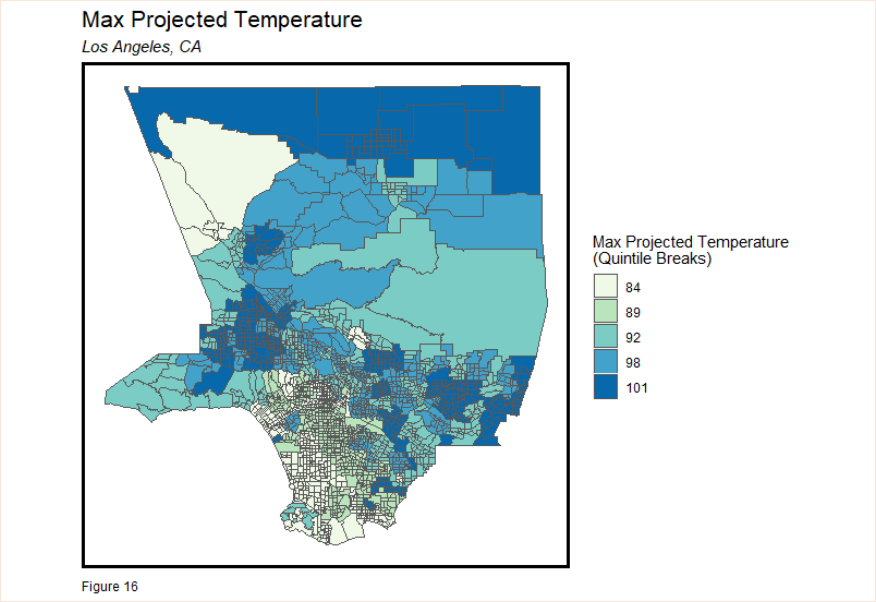


Figure 16

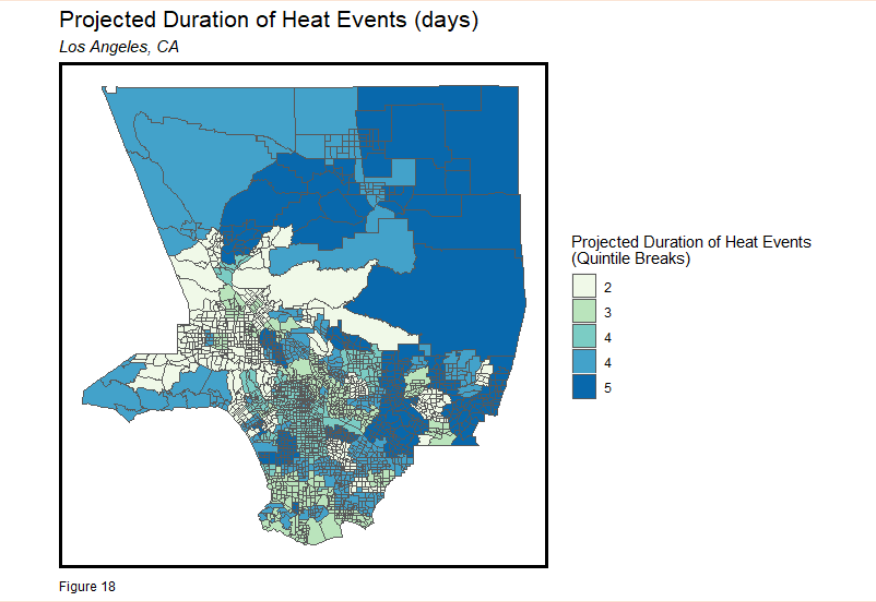


Figure 18

Areas with less green space and tree canopy coverage (closer to Downtown and San Fernando Valley) are expected to have more frequent and more devastating heat events

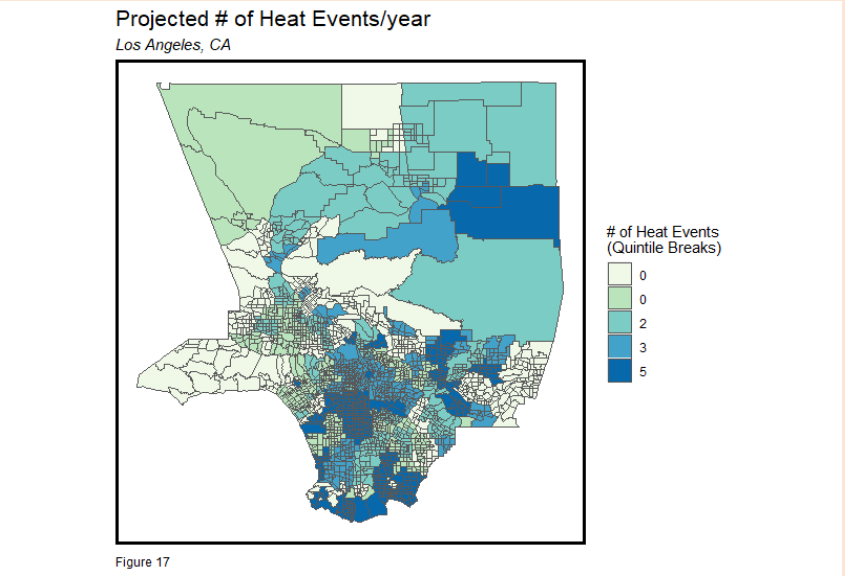


Figure 17

Results: Land Use Features

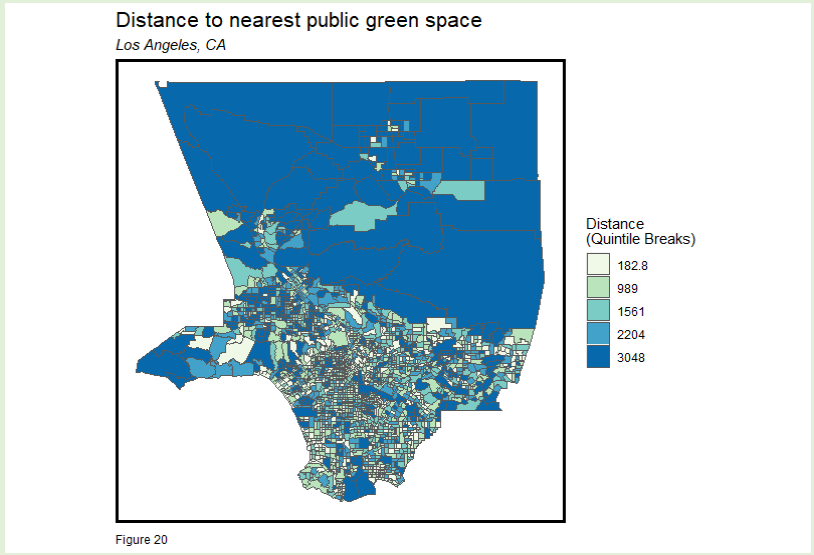


Figure 20

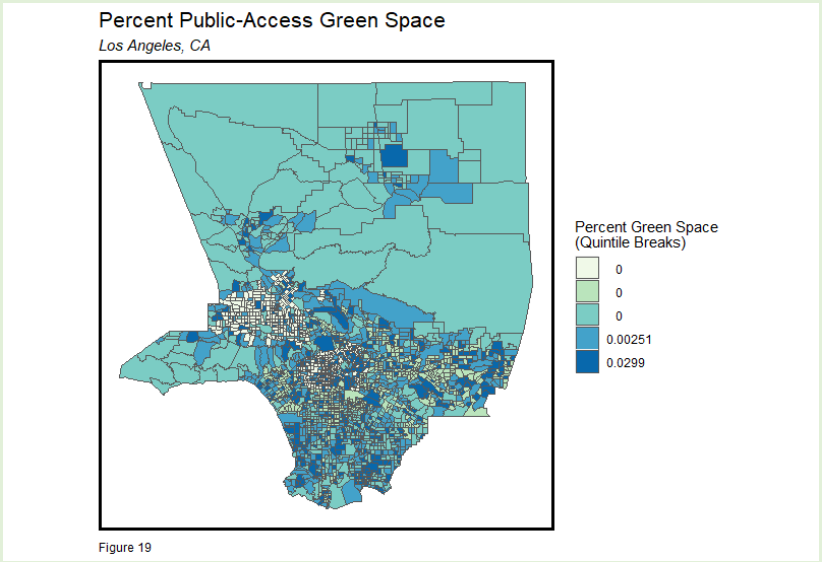


Figure 19

Remember that the Angeles Forest was filtered out of the green space layer and used as its own layer (why the northern tracts are bluer than supposed to be)

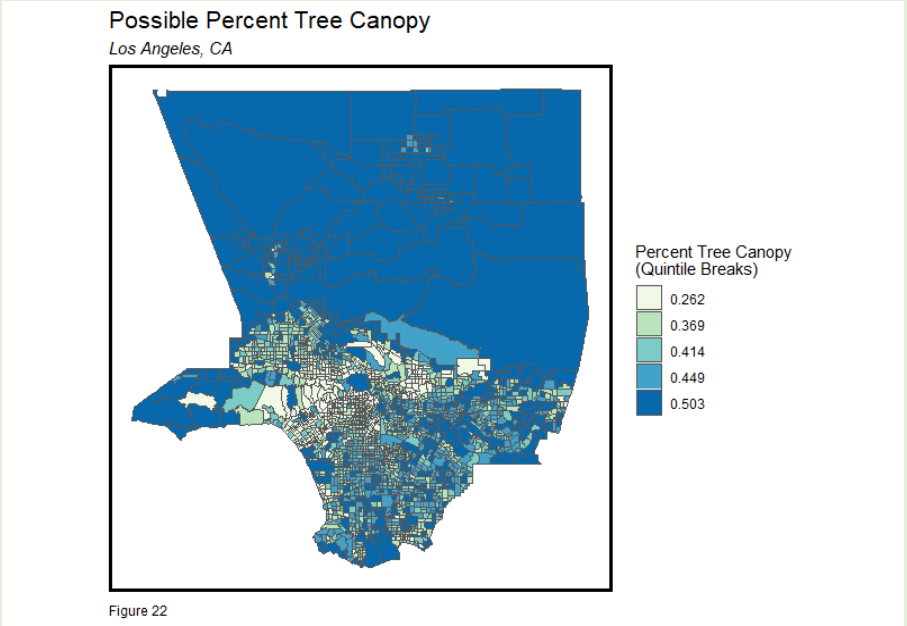


Figure 22

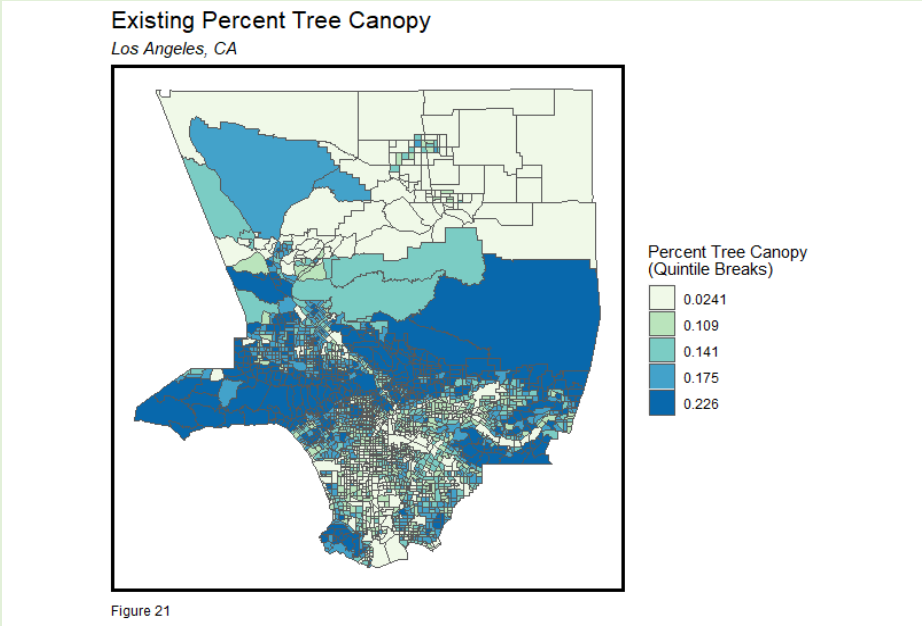


Figure 21

Results: Redlining Districts as a Contributor to Social and Physical Heat Vulnerability

Difference between Existing and Possible Tree Canopy Percent

Los Angeles, CA

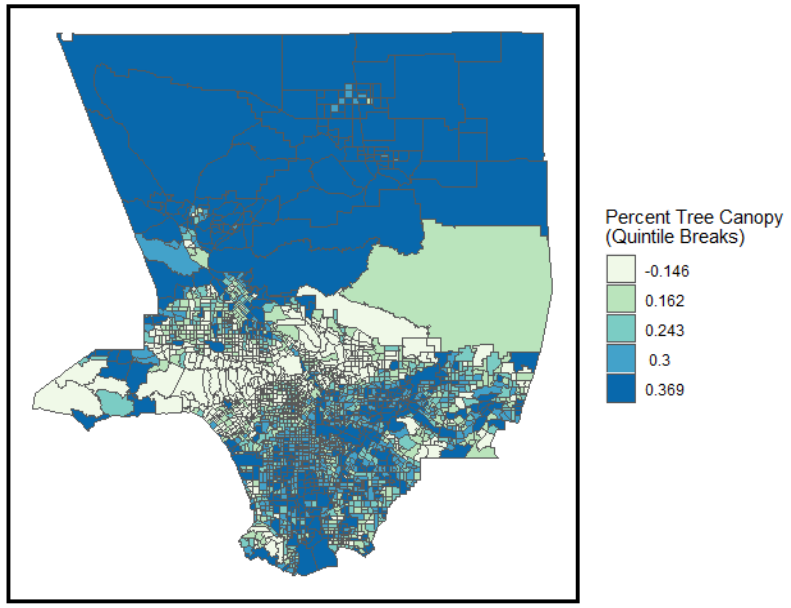


Figure 23

Red-lined Districts Layer

Los Angeles, CA

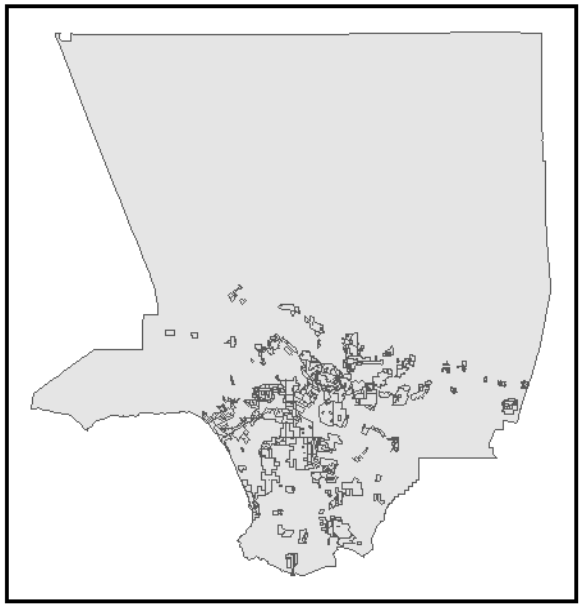
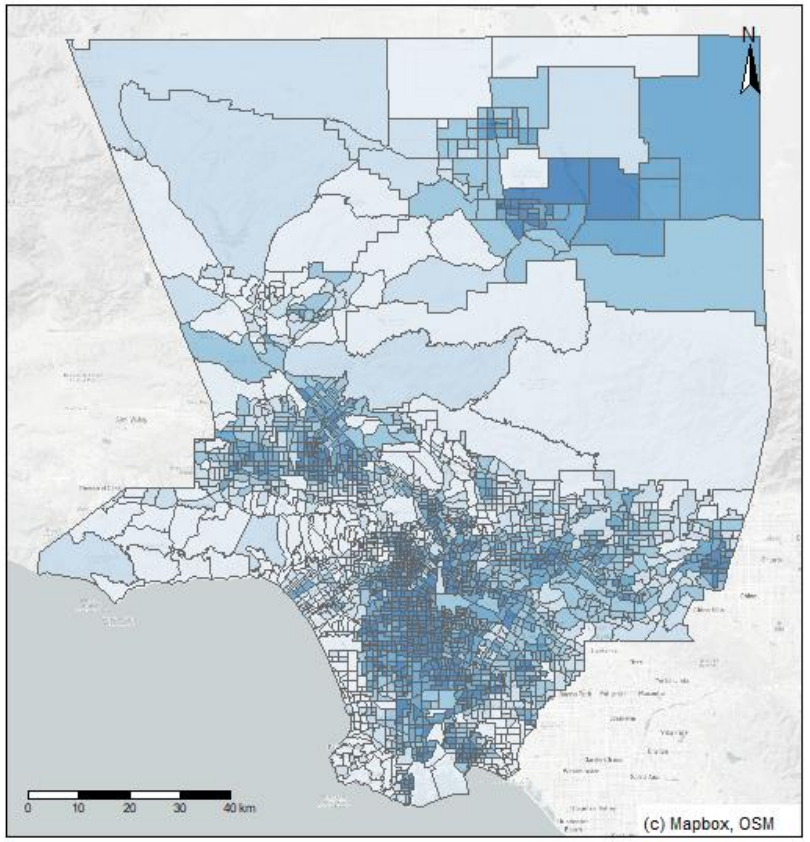


Figure 15

Historically, the allocation of community "beat-the-heat" resources and tree canopy percentage has been driven by relative affluence and racial composition of areas within the City (red-lined districts). Note the similarity between the possible/existing tree canopy percentage differences and the locations of the red-lined districts. For this reason, the effect of red-lining on the allocation of community "beat-the-heat" resources and tree canopy percentage will be considered in **Discussion**.

Results: Social and Physical Vulnerability Scores

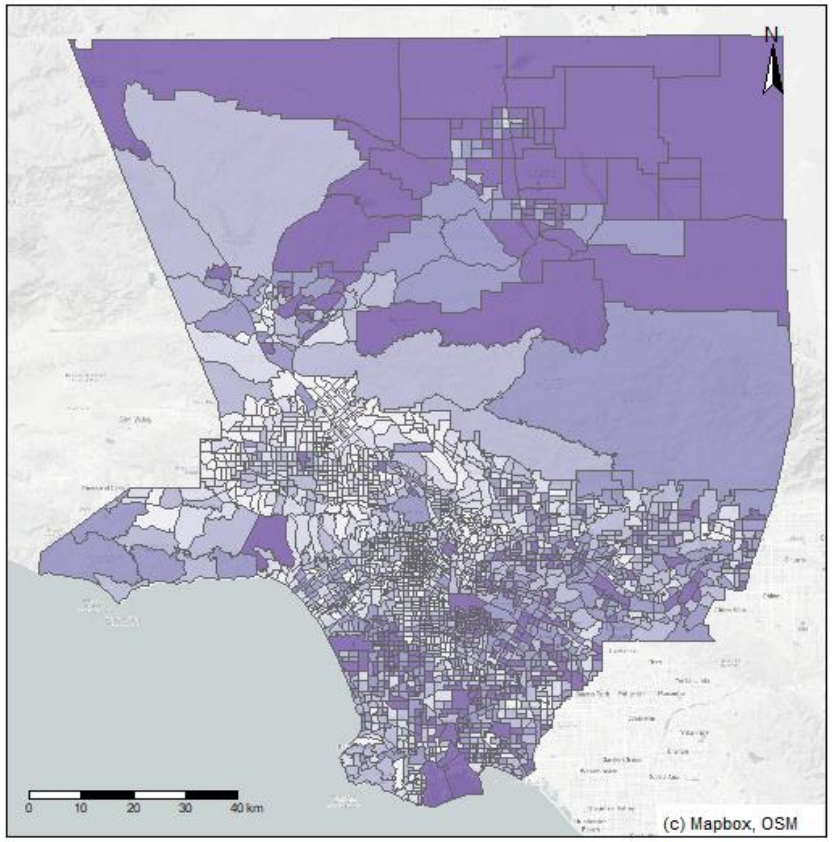
(Social Vulnerability Scores + Physical Vulnerability Scores) / 2 =



Social Vulnerability Index by Census tract

Social Vulnerability Index

1.000 to 2.157
2.157 to 2.653
2.653 to 3.103
3.103 to 3.547
3.547 to 4.260



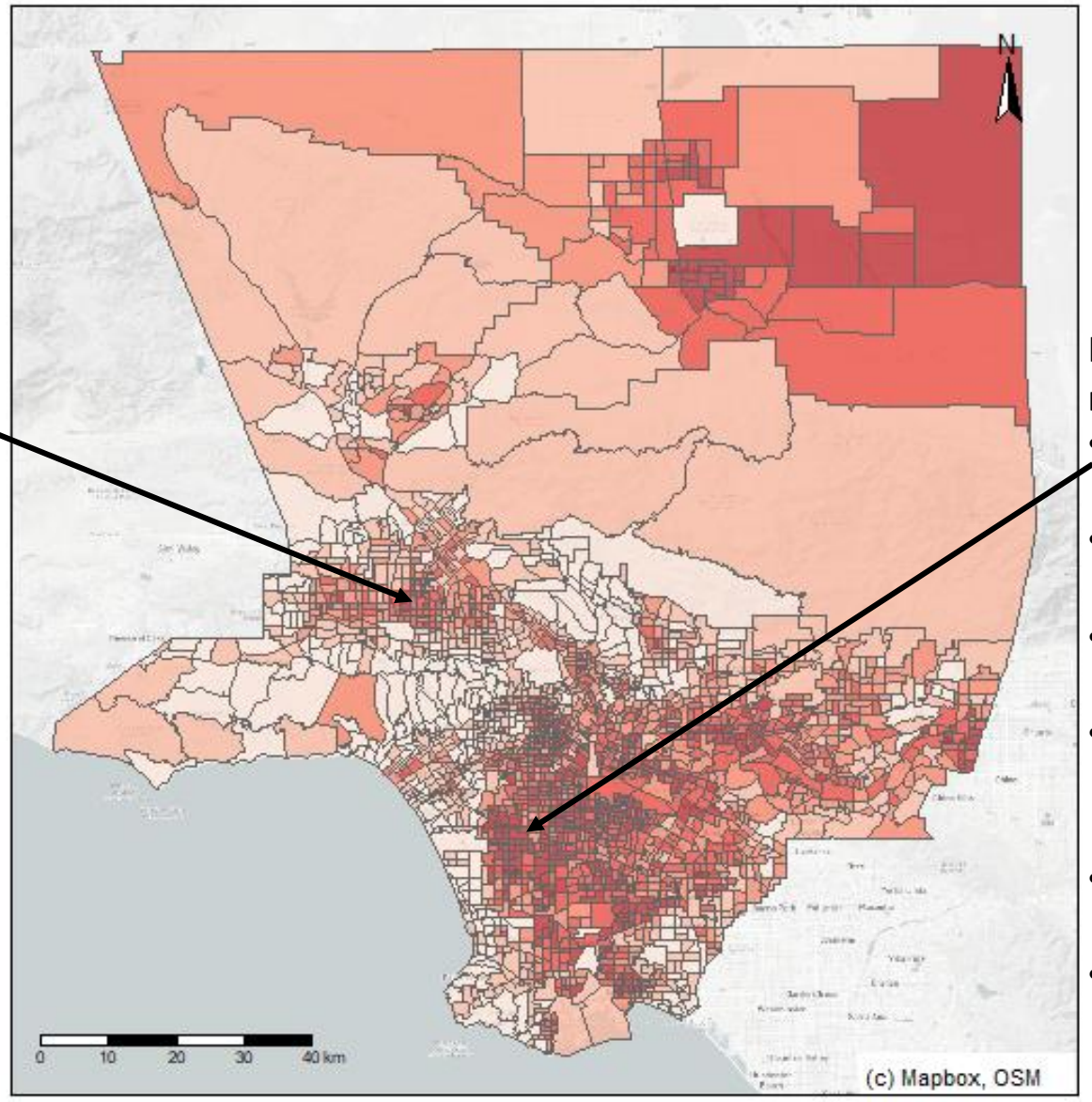
Physical Vulnerability Index by Census tract

Physical Vulnerability Index

1.873 to 2.533
2.533 to 2.820
2.820 to 3.093
3.093 to 3.407
3.407 to 4.100

Results: Overall Extreme Heat Vulnerability Index

According to my OWN calculations, my neighborhood of Van Nuys is in the most vulnerable quantile



Overall Extreme Heat Vulnerability Index
by Census tract

Overall Vulnerability Index

- 1.877 to 2.520
- 2.520 to 2.823
- 2.823 to 3.100
- 3.100 to 3.368
- 3.368 to 3.960

However, West Athens is the most vulnerable neighborhood:

- Completely impervious surface
- Directly adjacent to the Century Freeway
- Within 0.25 miles of largest heat island (LAX)
- 4.57 °F increase by 2050, compared to City average of 3.37 °F
- Median household income is two-fifths of City's
- 64% Latino/Hispanic, 35% African-American, 1% White

Conclusions and Recommendations

Potential Neighborhood Interventions for West Athens:

- City-run tax subsidy program to help individuals afford heat-dissipating utility installations and utility costs
- Work with local-interest, community stakeholders (like West Athens Neighborhood Alliance or TreePeople) to concurrently plant more trees/establish more greenspace, as well as educate residents about the costs and human health effects associated with extreme heat
- Use the app I made to pinpoint community "beat-the-heat" resources near where you live