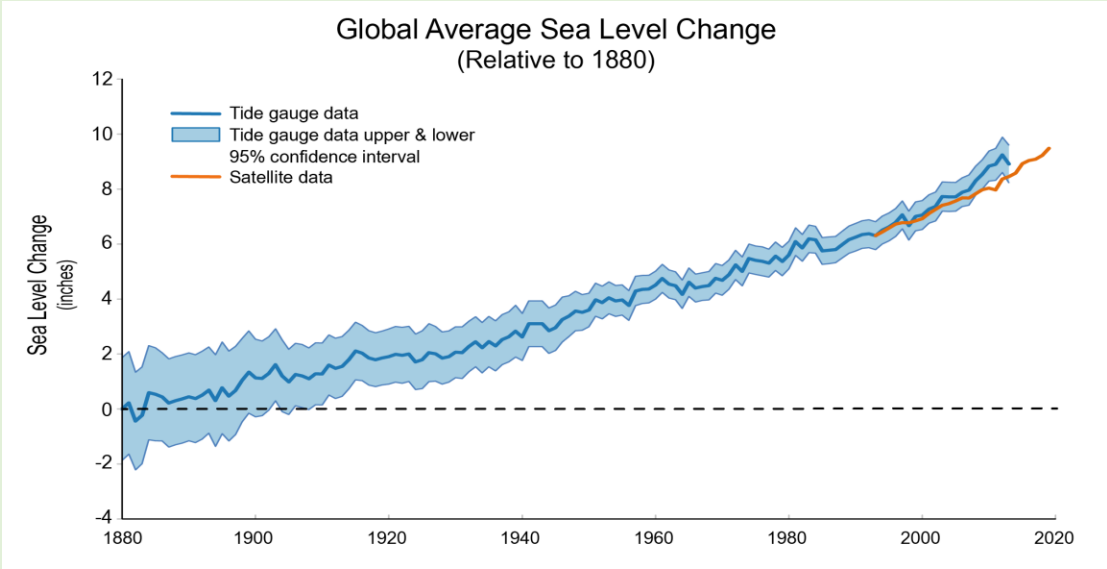
# Predicting Sea Level Rise Vulnerability in Los Angeles

by Aidan Cole

# Context

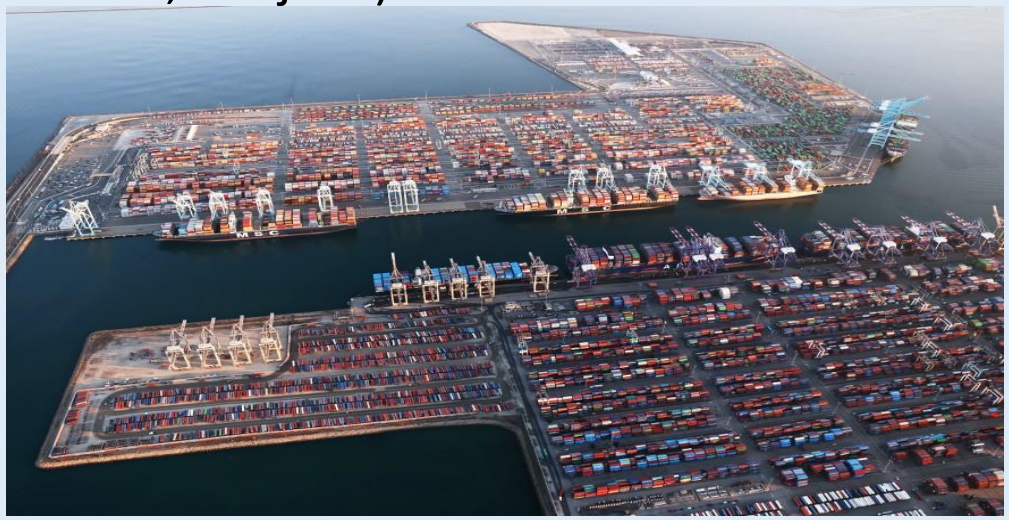
- Climate change is expected to usher in increasing temperatures, increased precipitation/cases of drought, and increased rates of sea level rise on a global scale (more sea level rise in last 30 years than last century)
- Climate researchers believe sea level rise will drive storm surge and wave run-up higher than current conditions, thus causing more frequent and extensive coastal flooding events
- Sea level rise is a multi-faceted, complicated issue (ex. Economic, social, and environmental issues associated)

More rise in last 30 than entire last century



# Los Angeles' Situation Pt. 1: Economy

- Sea level rise in LA will match global projections; increase of 5-24 in by 2050 and 17-66 in by 2100
- City owns and maintains coastal infrastructure (2 power and wastewater treatment plants, Port of LA) that is currently vulnerable
  - Port rakes in $63 bil for CA and $260 bil for US/year (40% of all imported goods, over 300,000 jobs)



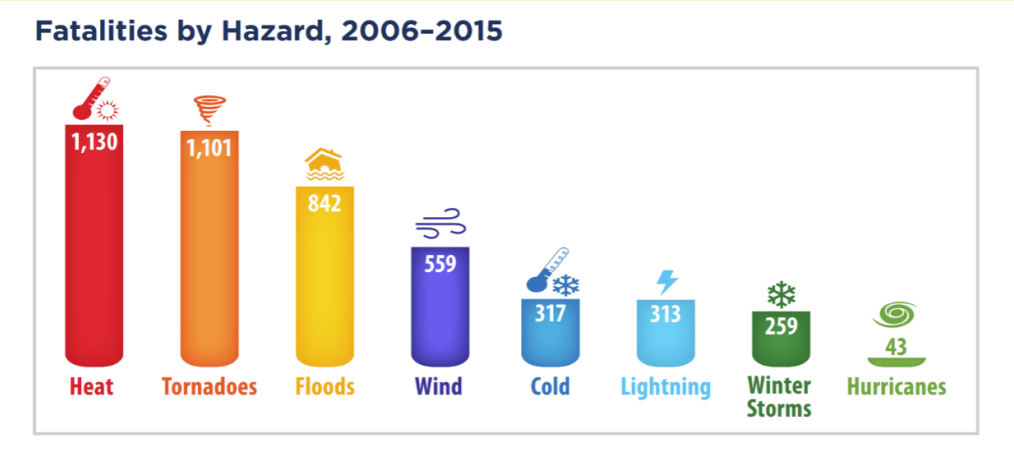
Port of LA

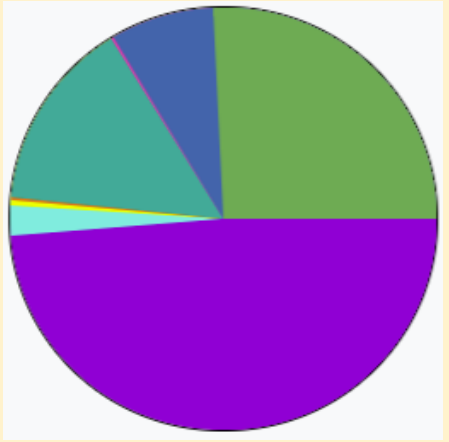
Coastal flooding event in Malibu, 2020

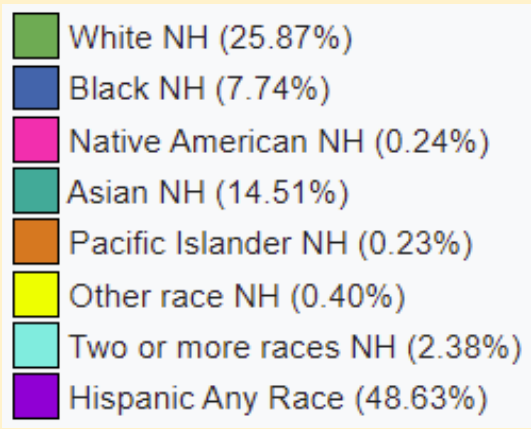
- Economy is reliant on beach tourism (41 million tourists/year = over $17 bil)
- For 10-year flood event, building losses: $410 mil with 0.5 m rise, $800 mil with 1.4 m rise (50% of properties RESIDENTIAL)

# Los Angeles' Situation Pt. 2: Social

- LA's cultural assets (i.e. museums and cultural centers) are deemed highly vulnerable to sea level rise because damage can affect buildings and their resources
  - Loss of culture and social cohesion
- City demographic makeup is extremely diverse in terms of race, per capita income, education level, etc., and varies spatially. Thus...
- Sea level rise affects different populations in different ways
  - Will exacerbate the underlying social preconditions of poverty; positive feedback loop
- Loss of jobs, residential homes, important roads and watersystems
  - 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
  - Drowning, hypothermia, electrocution, carbon monoxide poisoning, mold inhilation, starvation, mental issues
  - According to the Population Reference Bureau, flooding is the third most common natural disaster-related cause of death in the US and its death toll will only increase as a result of sea level rise





# Los Angeles' Situation Pt 3: Environmental

- Pollution of water systems from flooding is a huge concern, as trash and other toxic waste is swept up with excess water
  - A majority of LA's coastal zone is urbanized; urban waste is prevalent and close to water already
  - Human and ecological health implications
- Only ecological asset that lies within the City's jurisdiction that would be affected is the Ballona Wetlands Ecological Reserve
  - 600-acre reserve; largest remaining coastal wetland in LA county, providing a plethora of important ecosystem services like nutrient cycling, wave attenuation, species protection, and water purification
  - 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

Ballona Wetlands Ecological Reserve outlined in red

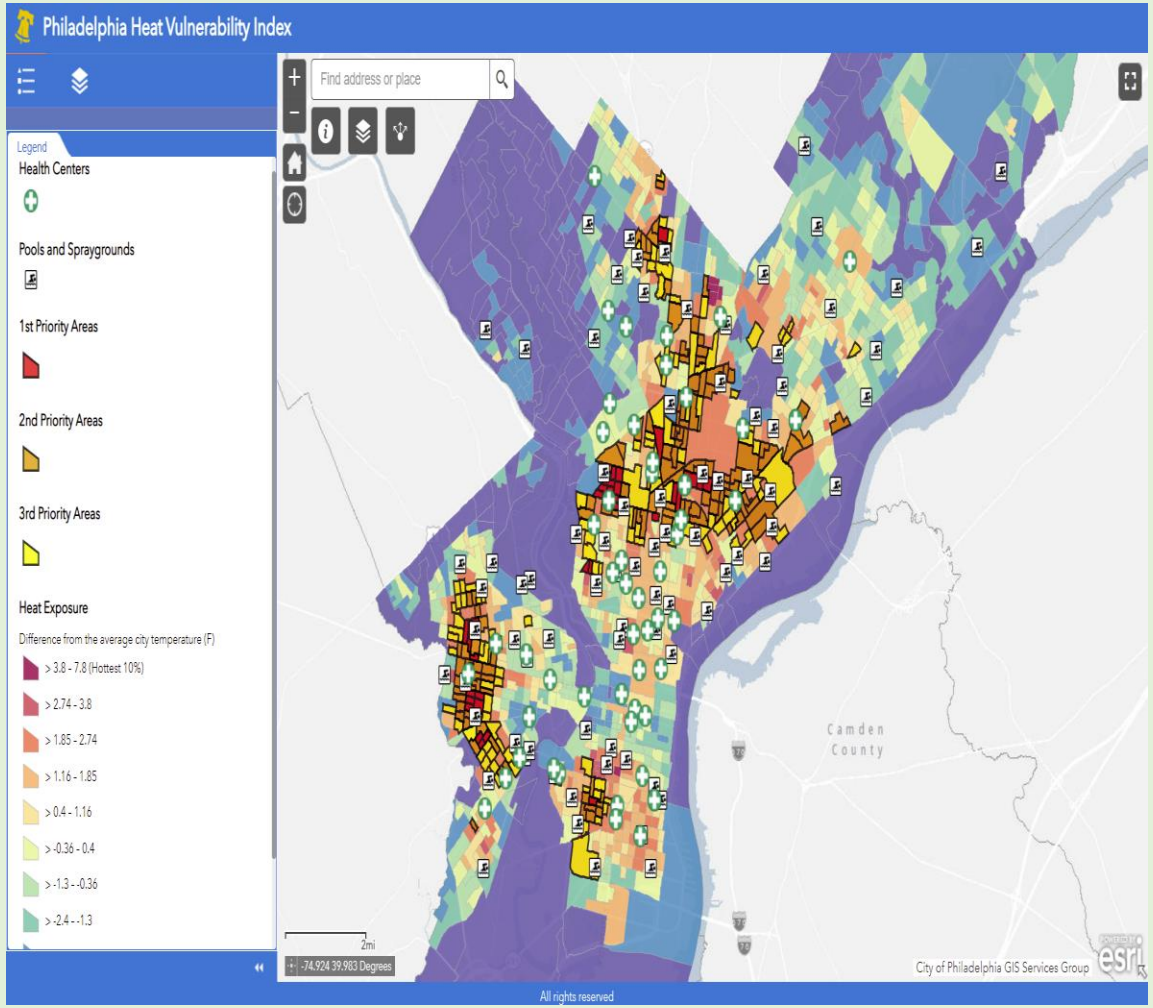
# Converging Implications and Question

**Issue**:

1. Sea level rise is a detriment to the economic, social, and environmental systems present within the city
2. The rate of sea level rise is only predicted to get worse in the future
3. Different populations and neighborhoods are affected differently depending on a number of factors, including proximity to water and medical facilities, 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 sea level rise?"

# 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 sea level rise?"

**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 in order to optimize the allocation of possible climate-adaption strategies

# Method

**Data**:

1. Scrape census tract demographic data from American Community Survey API to assess neighborhood social health (how economically and socially vulnerable)
    - Perhaps consider historical disenfranchisement data- like redlining- to see if any communities have additional obstacles to overcome that may not be overt
2. Raster data/DEM to determine elevation and land-use (how physically vulnerable); still yet to find a good, joinable source to use
3. Historic and current sea level rise and damage data from National Oceanic and Atmospheric Administration
4. Spatial features/proximity data (distance to water, nearest medical facility, Ballona Wetlands Ecological Reserve, structural community asset/landmark) 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 Sea Level Vulnerability Study

# Method: Social Vulnerability

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

- 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 groups), including:

**1) Socioeconomic status**

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

**2) Household Composition and Disability**

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

**3) Minority Status and Language**

- minority
- speaks English “less than well”

**4) Housing Type and Transportation**

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

# Method: Social Vulnerability Cont.

Using the FEMA and CDC models for social vulnerability as inspiration, and based on Los Angeles' previously discussed unique context, I decided to use the following social factors in my social vulnerability calculation:

- Racial context
- Immigrants and migrant laborers
- Populations with limited English proficiency
- Single-parent households
- Educational attainment
- Unemployment
- Per capita income
- Below poverty
- Individuals experiencing homelessness or displacement
- Populations over the age of 65 or under the age of 5
- Populations with limited cognitive or physical abilities
- Institutionalized populations, such as those in prisons and nursing homes, or individuals going through reentry (group quarters)
- Renters (renter vs owner occupied)
- Individuals with lack of vehicle access
- Number of at-risk cultural centers
- Redlining

# Method: Physical Vulnerability

A landmark paper published in 1994 by Gornitz et al established the Coastal Vulnerability Index (CVI), which highlights six physical variables that contribute to an area's vulnerability to sea level rise. The table below shows these variables, their descriptions, and their relative weights:

| | Ranking of coastal vulnerability index | | | | |
|---|---|---|---|---|---|
| | Very low | Low | Moderate | High | Very high |
| VARIABLE | 1 | 2 | 3 | 4 | 5 |
| Geomorphology | Rocky, cliffed coasts<br>Fiords<br>Fiards | Medium cliffs<br>Indented coasts | Low cliffs<br>Glacial drift<br>Alluvial plains | Cobble beaches<br>Estuary<br>Lagoon | Barrier beaches<br>Sand Beaches<br>Salt marsh<br>Mud flats<br>Deltas<br>Mangrove<br>Coral reefs |
| Coastal Slope (%) | > .2 | .2 – .07 | .07 – .04 | .04 – .025 | < .025 |
| Relative sea-level change (mm/yr) | < 1.8 | 1.8 – 2.5 | 2.5 – 2.95 | 2.95 – 3.16 | > 3.16 |
| Shoreline erosion/ accretion (m/yr) | >2.0<br>Accretion | 1.0 – 2.0 | -1.0 – +1.0<br>Stable | -1.1 – -2.0 | < - 2.0<br>Erosion |
| Mean tide range (m) | > 6.0 | 4.1 – 6.0 | 2.0 – 4.0 | 1.0 – 1.9 | < 1.0 |
| Mean wave height (m) | <.55 | .55 – .85 | .85 – 1.05 | 1.05 – 1.25 | >1.25 |

# Method: Physical Vulnerability Cont.

Using these variables as my initial physical vulnerability framework, I devised a new way to calculate CVI, including the following factors (would love to hear recommendations on this):

- % of green space/infrastructure/tree canopy
- Proximity to water
- Elevation
- Mean wave height
- Coastal slope (%)
- Relative sea level change
- Proximity to and number of medical and emergency assistance locations
- Proximity to Ballona Wetlands Ecological Preserve
- % property ownership or land use (ex. residential, commercial)
- Relative "pollution burden"

# Method: Physical Vulnerability Cont.

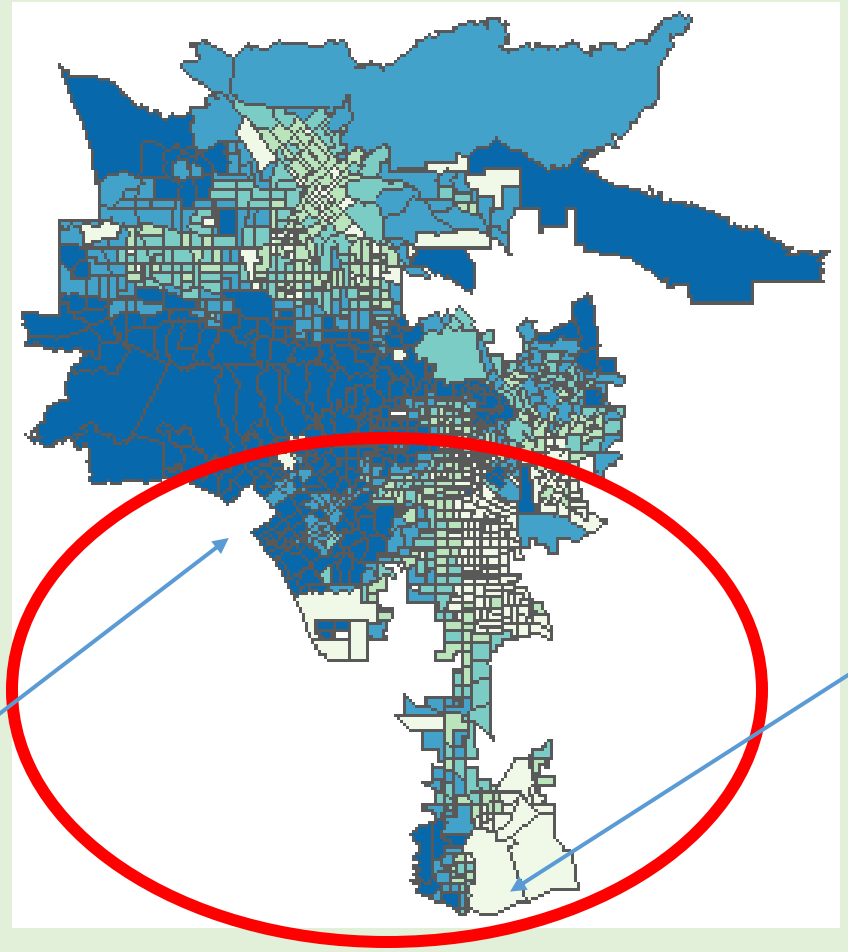
The California Office of Environmental Health Hazard Assessment (OEHHA) provides a screening methodology that identifies the factors that contribute to a community's relative "pollution burden":

- Pollution burden = the average of pollution indicators (drinking water contaminant index, toxic release concentrations, groundwater threats, impaired water bodies, and solid/hazardous waste concentrations, etc.)
- Because inundated water acts as a conveyant for pollutants to get into our water systems (human/environmental health implications), then the relative pollution burden in an area factors into that area's vulnerability (should I factor this into physical or social vulnerability?)

# Results so far

```
tracts19 <-
  get_acs(geography = "tract", variables = c("B01003_001E","B02001_002E","B02001_003E",
                                             "B03002_003E","B02001_005E","B19013_001E",
                                             "B15002_015E","B15002_032E","B06012_002E",
                                             "B01001_020E","B01001_021E","B01001_022E",
                                             "B01001_023E","B01001_024E","B01001_025E",
                                             "B01001_044E","B01001_045E","B01001_046E",
                                             "B01001_047E","B01001_048E","B01001_049E",
                                             "B01001_003E","B01001_027E","B01001_007E",
                                             "B01001_008E","B01001_009E","B01001_010E",
                                             "B01001_011E","B01001_012E","B01001_013E",
                                             "B01001_014E","B01001_015E","B01001_016E",
                                             "B01001_017E","B01001_018E","B01001_019E",
                                             "B01001_031E","B01001_032E","B01001_033E",
                                             "B01001_034E","B01001_035E","B01001_036E",
                                             "B01001_037E","B01001_038E","B01001_039E",
                                             "B01001_040E","B01001_041E","B01001_042E",
                                             "B01001_043E","B18101_010E","B18101_013E",
                                             "B18101_029E","B18101_032E","B19301_001E",
                                             "B23025_005E","B18104_007E","B18104_010E",
                                             "B18104_023E","B18104_026E","B08006_008E",
                                             "B08006_002E","B08014_002E","B05009_013E",
                                             "B05009_031E","B08006_001E","B26001_001E",
                                             "B06007_005E","B06007_008E","B05001_005E",
                                             "B05001_006E","B07001PR_050E","B25036_013E"
                                             "B25036_002E","B25001_001E","B01002_001E",
                                             "B01001_004E","B01001_005E","B01001_006E",
                                             "B01001_028E","B01001_029E","B01001_030E"),
          year=2019, state=06, county=037, geometry=T, output='wide') %>%
  st_transform('EPSG:3498') %>%
```

Easier way to find Census variables?




Having trouble filtering out Census tracts that are in LA County but not the City, also those that physically cannot be impacted by sea level rise (SFV, Calabasas, Pasadena)

# Results so far Cont.

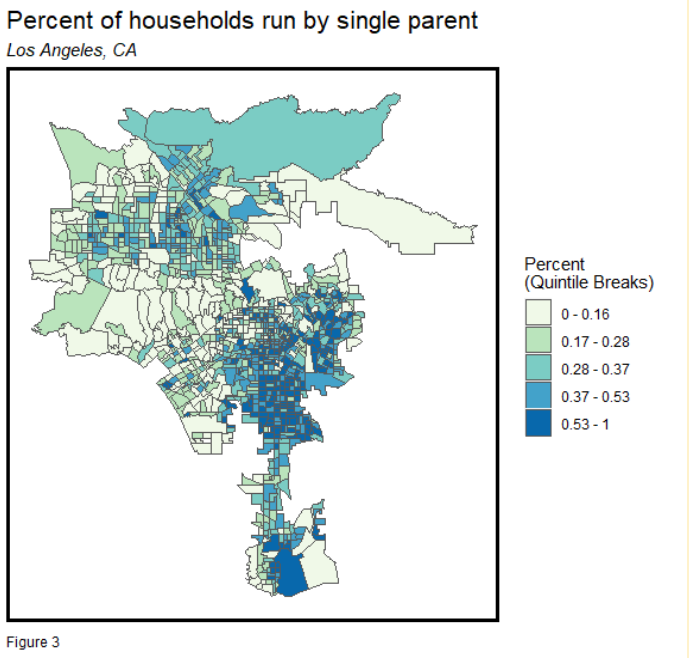


Figure 3

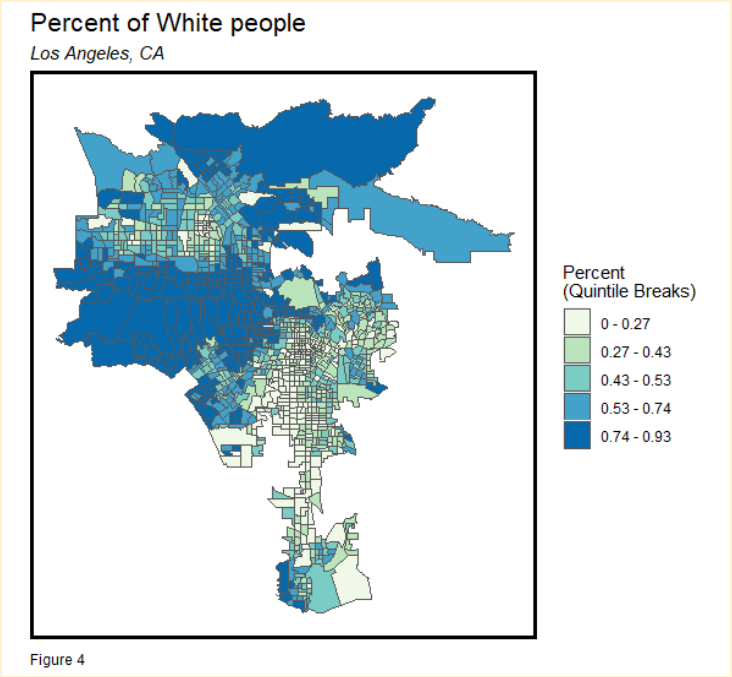


Figure 4

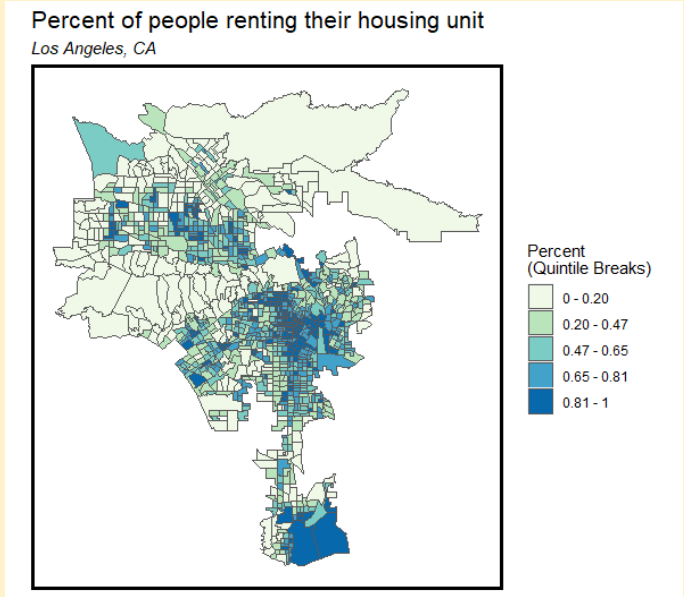


Figure 6

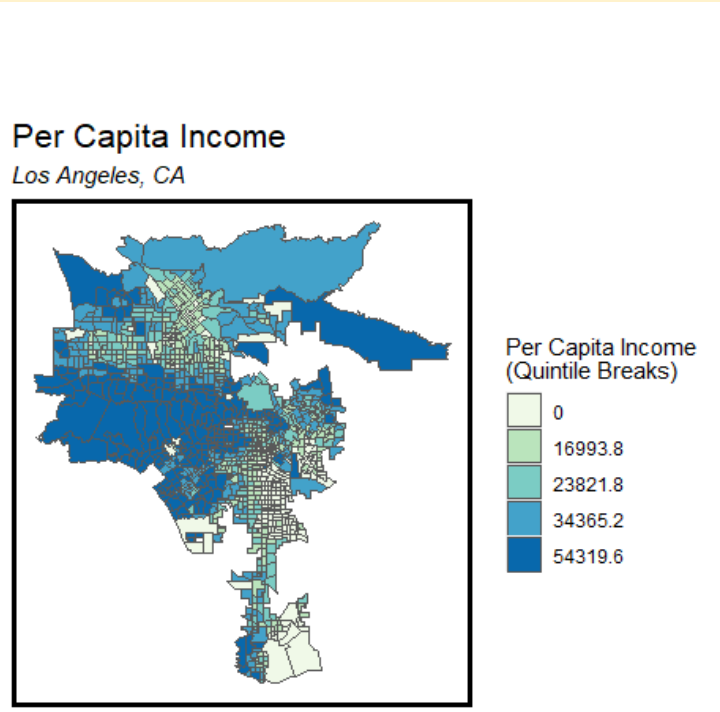


Figure 1

Notice the Southern-most part of the City is mostly non-white and low income. Coincidentally, this is also the area with the highest percentage of renters and single parent households.

# Results so far Cont.

Historical/Cultural Sites

*Los Angeles, CA*

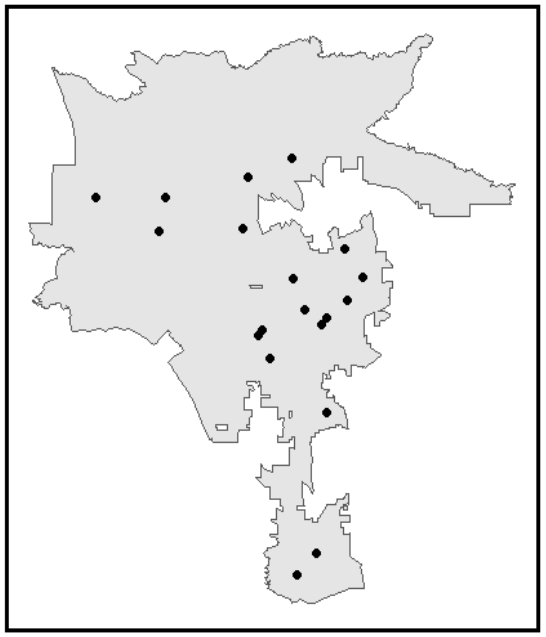


Figure 3

Emergency Preparedness Sites

*Los Angeles, CA*

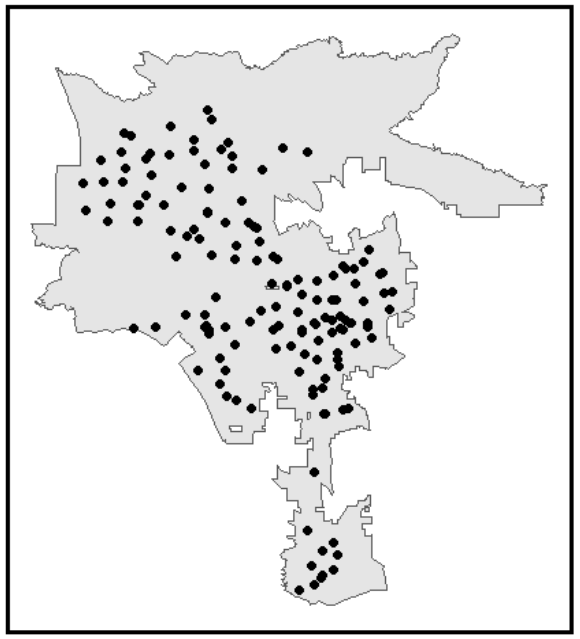


Figure 4

Hospitals and Urgent Care Sites

*Los Angeles, CA*

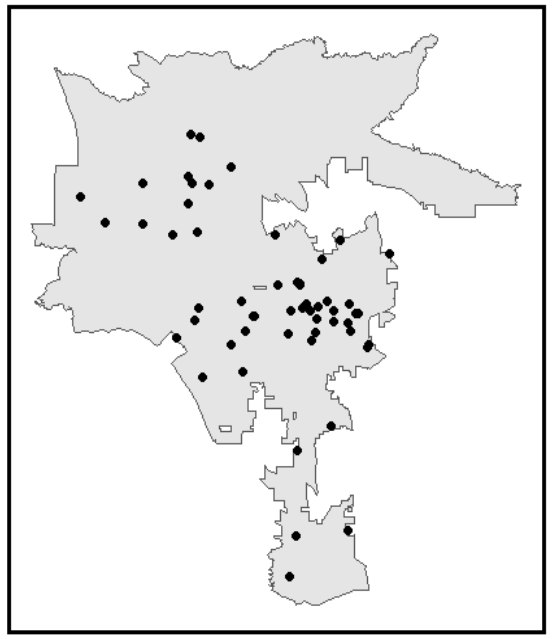
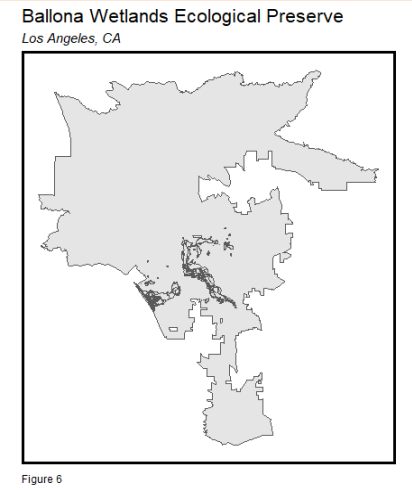


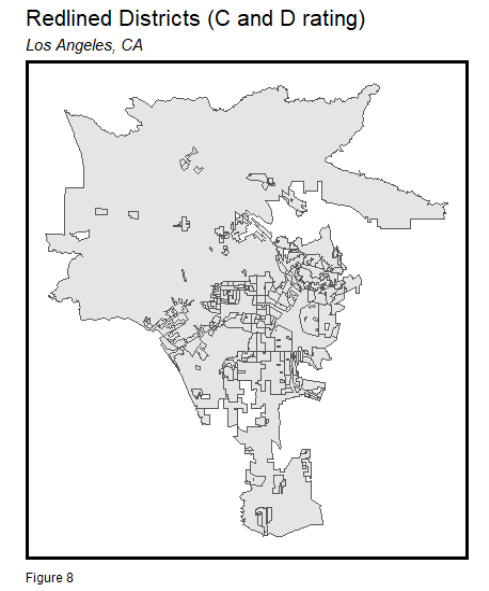
Figure 5

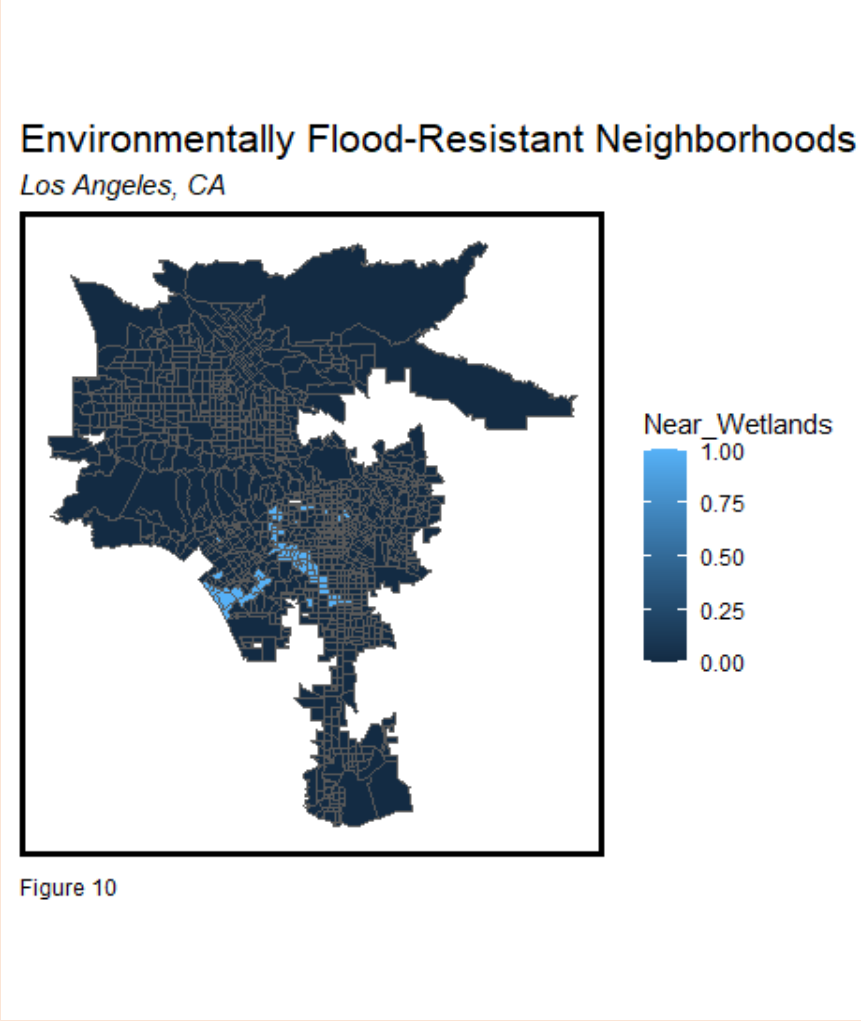
Currently, I am just doing distance to the nearest "thing" as a feature (converting Tract polygon to centroid point and calculating distance between that point and closest "thing" point), but not all people in the Tract live directly in the center.

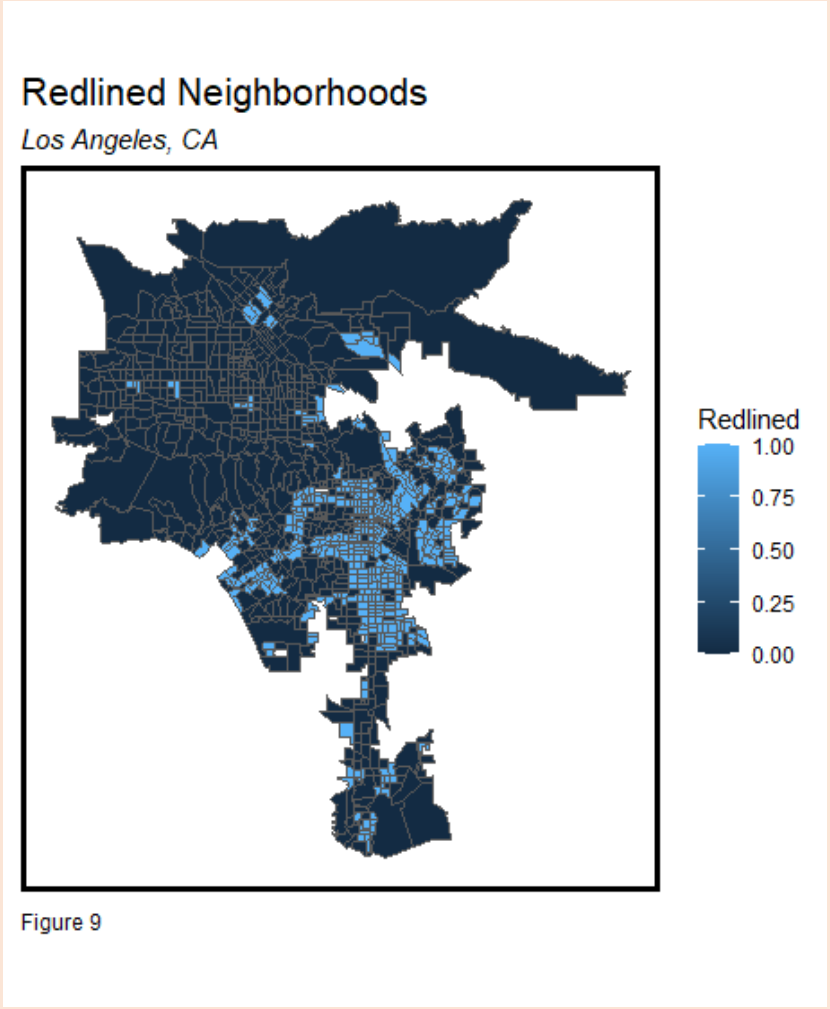
Should I instead cast a fishnet over the map and get the count of "things" per Tract?

# Results so far Cont.



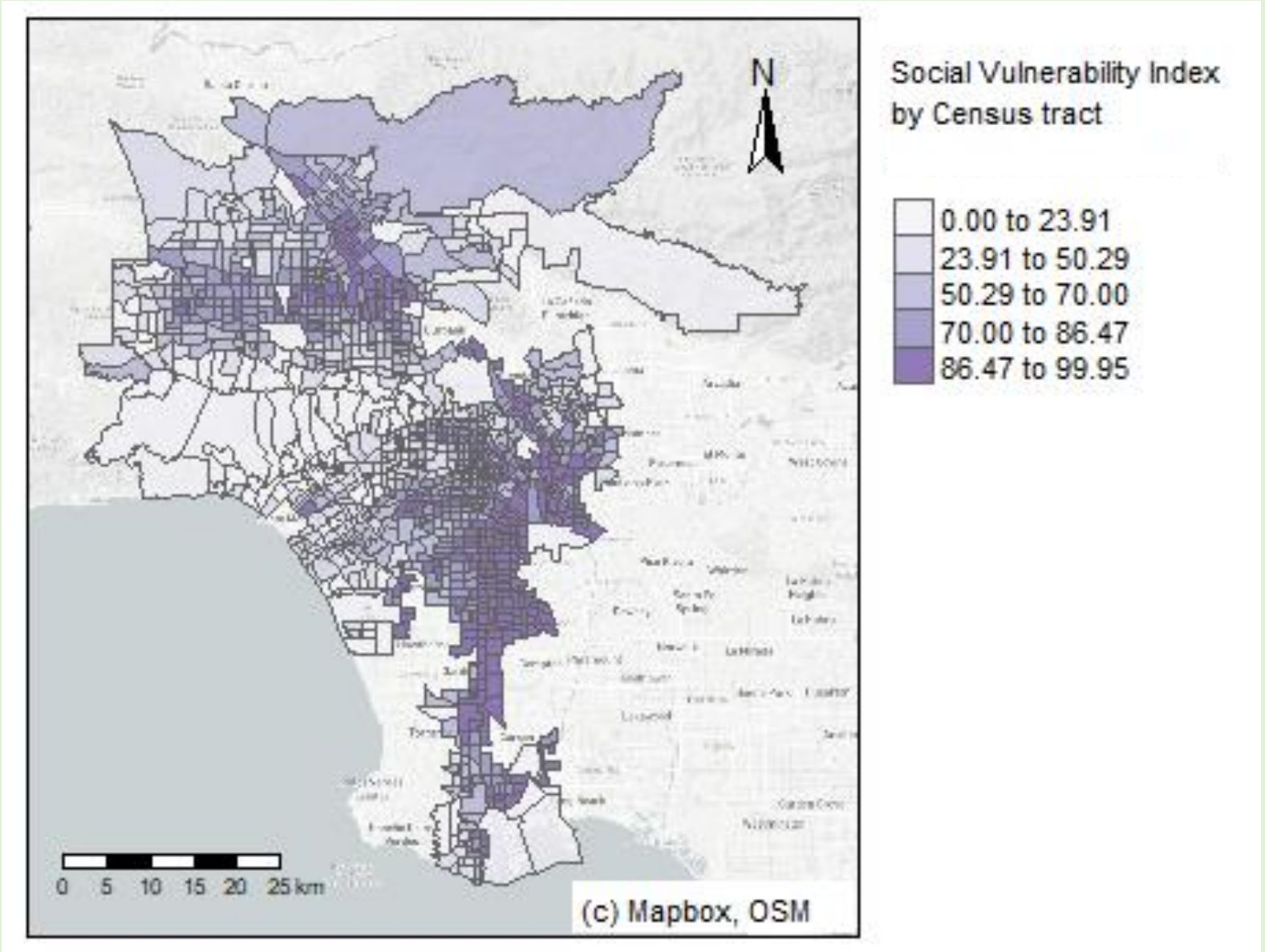




Want to add % green space to this environmentally flood-resistant neighborhood feature

# Results so far: MY FIRST DELIVERABLE?!




Do you think I left something out of my calculation? Am I considering too much/too little?

# Next Steps

**So Far**:

- In-depth research on topic (global context, local context, predicted effects, possible adaption strategies, what factors are most important in calculating risk score), gathered over 10 sources, written 75% of briefing paper
- Calculated Social Vulnerability Index and produced map

**Next Steps**:

- Finalize data collection for physical vulnerability (sea-level rise, elevation, % green space, etc.)
- Calculate Physical Vulnerability Index using Gornitz framework and produce map
- Overlay Social and Physical Vulnerability Index maps to find place where climate-adaptive action should be rolled out first
- Provide recommendations on what


# Questions/ Feedback?

Thank You!