Sea Level Rise & the U.S. Coast

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Introduction

This research project aims to understand social vulnerabilities as well as intrinsic strengths and community resilience in different states with respect to climate change resilience. The primary research vehicle is a comparative study of demographic conditions in Puerto Rico, Texas, Florida, Louisiana, and Hawaii. The analysis is directed towards understanding relationships between resilience and income levels, population densities, and overall infrastructural capacities of the states being studied. The primary outcome of this research is expected to yield insight into the differences in preparation levels, economic strength, and community resilience and how these factors affect capacities to mitigate the effect of climate change-induced disasters, and where investment could be directed to bolster capacity for resilience and long-term adaptation.

Research Methodology

A historical lens is applied to coastal communities in states such as Texas, Florida, Hawaii, and Louisiana to try to understand what the data presently shows pertaining to the place profile and demographics. The point of reference is the U.S. territory of Puerto Rico, which is compared against coastal communities in Texas, Florida, Louisiana, and Hawaii. Firstly, a justification of analysis level is carried out based on the areas of impact. For instance, Fig. 1 shows the history of strong storms that made landfall in Texas.

Hurricanes

The figure depicts Category 4 or Higher Hurricanes that have reached land, and it is evident that multiple counties inland have been affected by the hurricanes. This indicates that county level analysis would be ideal in terms of scale, and would thus paint a picture connected to the ground reality as compared to a more macro-level analysis.

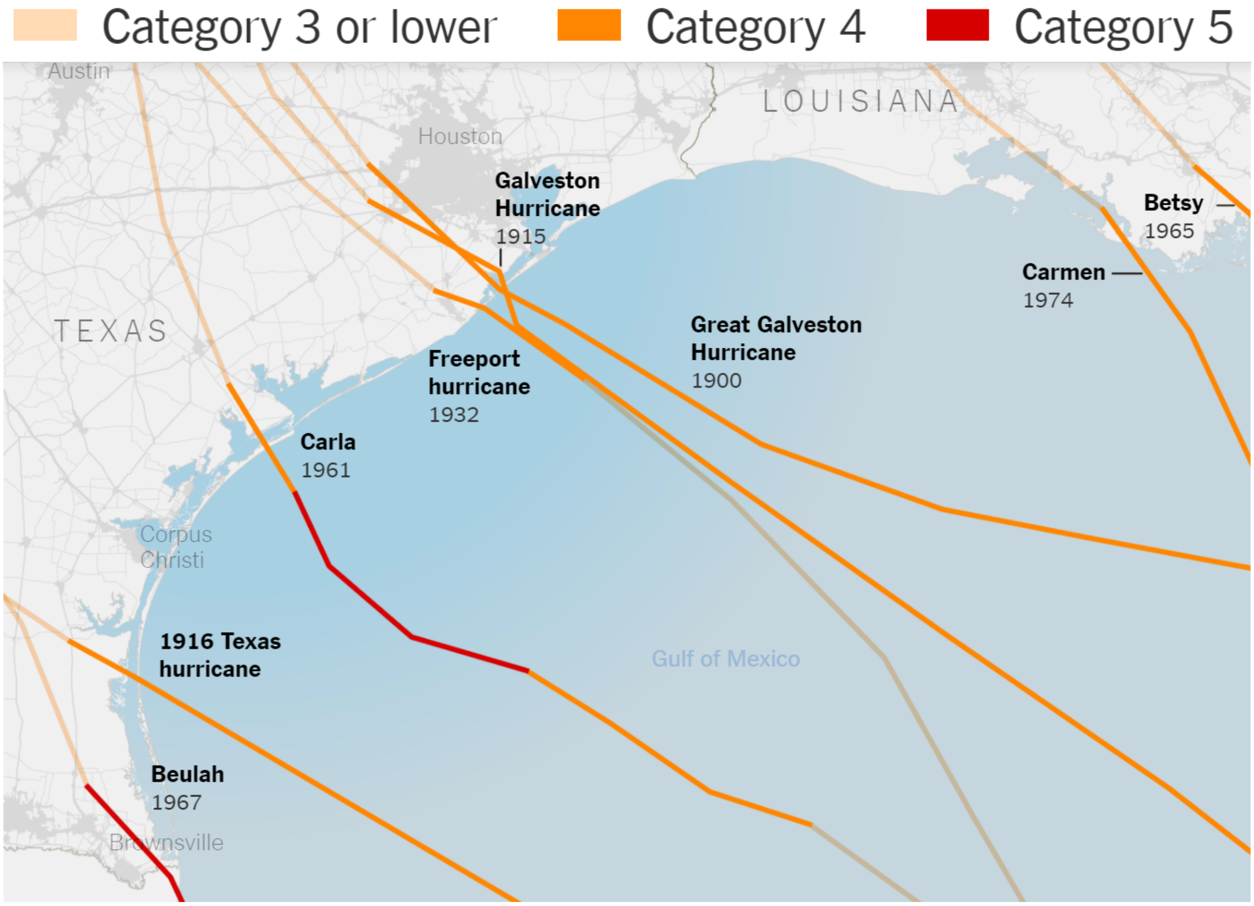


Fig. 1. Texas Historic Hurricane Paths (1900-1974)

In 2017, Hurricane Maria swept across the length of Puerto Rico devastating several communities further inland. By the time Maria made landfall in Puerto Rico, it had developed into a Category 4 storm which resulted in 2,975 fatalities (Baldwin, 2018). Originally, the research planned to focus only on the municipality of Loíza. However, it is now considered that a larger scale of analysis would be more prudent. Thus, the entire territory of Puerto Rico will be compared with coastal communities in the mainland states. This consideration also addresses any disparities in sizes of the places being analyzed.

Fig. 2. Path of Hurricane Maria (2017)

Sea-Level Rise Level Modeling

National Center for Space Studies (CNES 2) & NASA, in partnership with the European Organization for the Exploitation of Meteorological Satellites (EUMESTAT) and the National Oceanic and Atmospheric Administration (NOAA) launched four satellites, namely Jason-1, Jason-2, Jason-3 & TOPEX/Poseidon to monitor and measure sea level rise. The first satellite, TOPEX/Poseidon began operating in orbit in 1993 and was operational up till 2006. Jason-3 is the latest satellite to be launched from the Vandenberg AFB Space Launch Complex, by SpaceX. As of 2019, it is in orbit and active service (Patel, 2019).

Projections for sea level rise scenarios up to the year 2100 are carried out in this thesis. Using the observed data from 1993 to 2017 as a baseline for reference, future sea level rise projections have been calculated by quadratic extrapolation. For these projections, the following assumptions are made, based on the findings of the NASA Goddard Spaceflight Center (NASA Goddard Spaceflight Center, 2018) (Nerem, et al., 2018):

1. The observed trends are manifest from accurately measured satellite altimetry data (with an acceptable error margin of ± 0.8 mm)
2. The average constant rate of GMSL rise is assumed to be 3 ± 0.4 mm/yr
3. The average constant rate of SLR along the Indian coast is assumed to be 1.3 mm/yr
4. The acceleration rate for sea level rise due to the melting of polar ice caps is taken as 0.084 ± 0.025 mm/yr2
5. Corrections of ± 0.025 mm/yr2 for the acceleration component of SLR incorporate errors such as El Niño Southern Oscillations and the Pinatubo effect

The modeling was original carried out for twelve scenarios of sea-level rise for comparison with the scenario on the Indian Coast (for the state of Gujarat). The SLR model is adjusted to reflect sea-level rise trends for Puerto Rico, Hawaii, and the southern U.S. coast. The data is sourced from the National Oceanic and Atmospheric Administration (NOAA) (Patel, 2019):

(Florida (FL)): The relative sea level trend is (2.5) millimeters/year with a 95% confidence interval of +/- 0.15 mm/yr based on monthly mean sea level data from 1913 to 2020 which is equivalent to a change of 0.82 feet in 100 years.

(Hawaii (HI)): The relative sea level trend is (1.55) millimeters/year with a 95% confidence interval of +/- 0.21 mm/yr based on monthly mean sea level data from 1905 to 2020 which is equivalent to a change of 0.51 feet in 100 years.

(Louisiana (LA)): The relative sea level trend is (9.16) millimeters/year with a 95% confidence interval of +/- 0.4 mm/yr based on monthly mean sea level data from 1947 to 2020 which is equivalent to a change of 3.01 feet in 100 years.

(Louisiana (LA)): The relative sea level trend is (6.16) millimeters/year with a 95% confidence interval of +/- 0.74 mm/yr based on monthly mean sea level data from 1958 to 2020 which is equivalent to a change of 2.02 feet in 100 years.

(Puerto Rico (PR)): The relative sea level trend is (2.09) millimeters/year with a 95% confidence interval of +/- 0.37 mm/yr based on monthly mean sea level data from 1962 to 2020 which is equivalent to a change of 0.69 feet in 100 years.

```
## # A tibble: 109 x 8
##    `Sea Level Rise Pr~ ...2     ...3     ...4     ...5     ...6     ...7     ...8
##    <chr>               <chr>    <chr>    <chr>    <chr>    <chr>    <chr>    <chr>
##  1 YEAR                III      XII      FL       HI       LA       TX       PR
##  2 1993                3        3        2.09     1.55     9.16     6.1599~ 1.3
##  3 1994                6        3.04199~ 2.1319~ 1.5919~ 9.202    6.202    1.3419~
##  4 1995                9.00000~ 6.16800~ 4.3479~ 3.2680~ 18.488   12.488   2.7680~
##  5 1996                12       9.37800~ 6.6479~ 5.0279~ 27.857~ 18.858~ 4.2779~
##  6 1997                15       12.6720~ 9.032    6.8719~ 37.311~ 25.311~ 5.8719~
##  7 1998                18       16.0499~ 11.5     8.8000~ 46.85    31.849~ 7.55
##  8 1999                20.9999~ 19.512   14.051~ 10.811~ 56.471~ 38.472~ 9.3119~
##  9 2000                23.9999~ 23.0580~ 16.687~ 12.907~ 66.177~ 45.177~ 11.158~
## 10 2001                26.9999~ 26.6879~ 19.407~ 15.087~ 75.967~ 51.968~ 13.087~
## # ... with 99 more rows
```

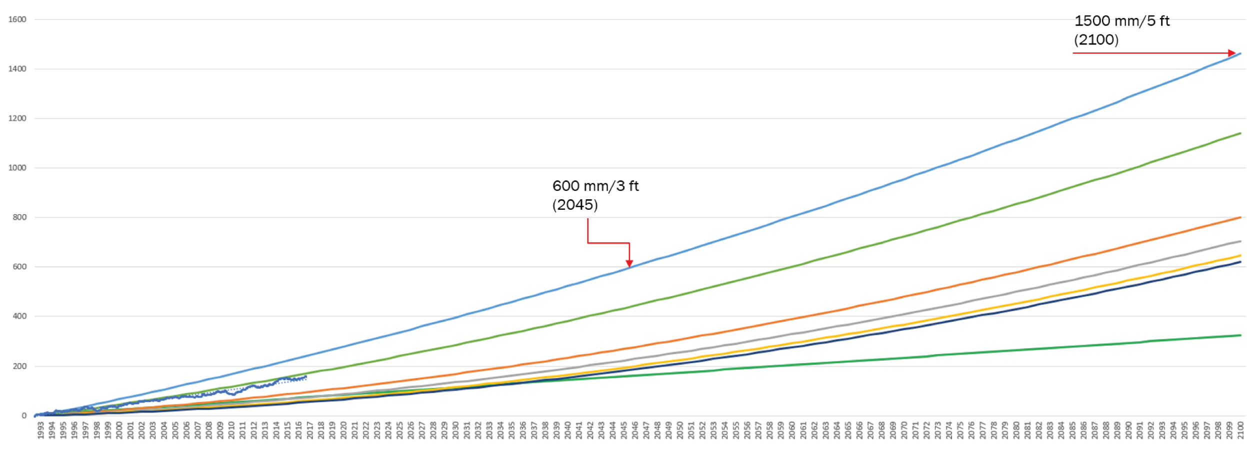


Fig. 3. Sea Level Rise Trends (1993-2100)

The chart above shows sea-level rise modeled up to 2100 for Puerto Rico (PR) and the states of Florida (FL), Hawaii (HI), Louisiana (LA), and Texas (TX). The best case trendline (III) shows an optimistic scenario. SLR is predicted up to the year 2100 for the five cases as well as two baseline scenarios. The model is based on observed trends from 1993 to 2017 as observed by NASA's altimetry satellites JASON and TOPEX/Poseidon

Data Sources

The research utilizes data obtained from the following sources:

- ArcGIS Living Atlas of the World (for mapping using in-built GIS data)
- U.S. Census Bureau & American Community Survey (for demographic data for place profile) ACS 5-Year Estimate 2019 B17020: POVERTY STATUS IN THE PAST 12 MONTHS BY AGE ACS 5-Year Estimate 2019
- U.S. Census Bureau TIGER/Line Shapefiles (for map representations)
- Articles from periodicals (for historical context)

Data Description, Preliminary Analysis and Interpretation:

Demographics

```
## Use of data from IPUMS USA is subject to conditions including that users should
## cite the data appropriately. Use command ‘ipums_conditions()‘ for more details.
```

Source: Steven Ruggles, Sarah Flood, Sophia Foster, Ronald Goeken, Jose Pacas, Megan Schouweiler and Matthew Sobek. IPUMS USA: Version 11.0 [dataset]. Minneapolis, MN: IPUMS, 2021. https://doi.org/10.18128/D010.V11.0

This dataset will be used to handle demographic analyses. The cases have been selected through IPUMS USA.

Population Density

The population densities of each region is mapped below.

Fig. 4. Population Density By County (2019)

Harris County in Texas as well as the counties on Florida's eastern coastline are relatively the most densely populated counties. The population densities in Louisiana are minimal when compared to the densest areas in the studied region. The concentration of population in Texas and Florida is primarily attributable to the location of Houston and Miami respectively. These large population centers are most vulnerable in purely physical terms; this inference might belie the fact that two of the largest cities in the United States would have an exponentially higher resilience capacity as compared to the smaller, less populated counties on the coast. Houston and Miami have greater access to the state's resources and might be better poised to combat climate change and the associated hazards. Thus, a this report recommends a county level analysis represented on the state level to better direct capacity building investment.

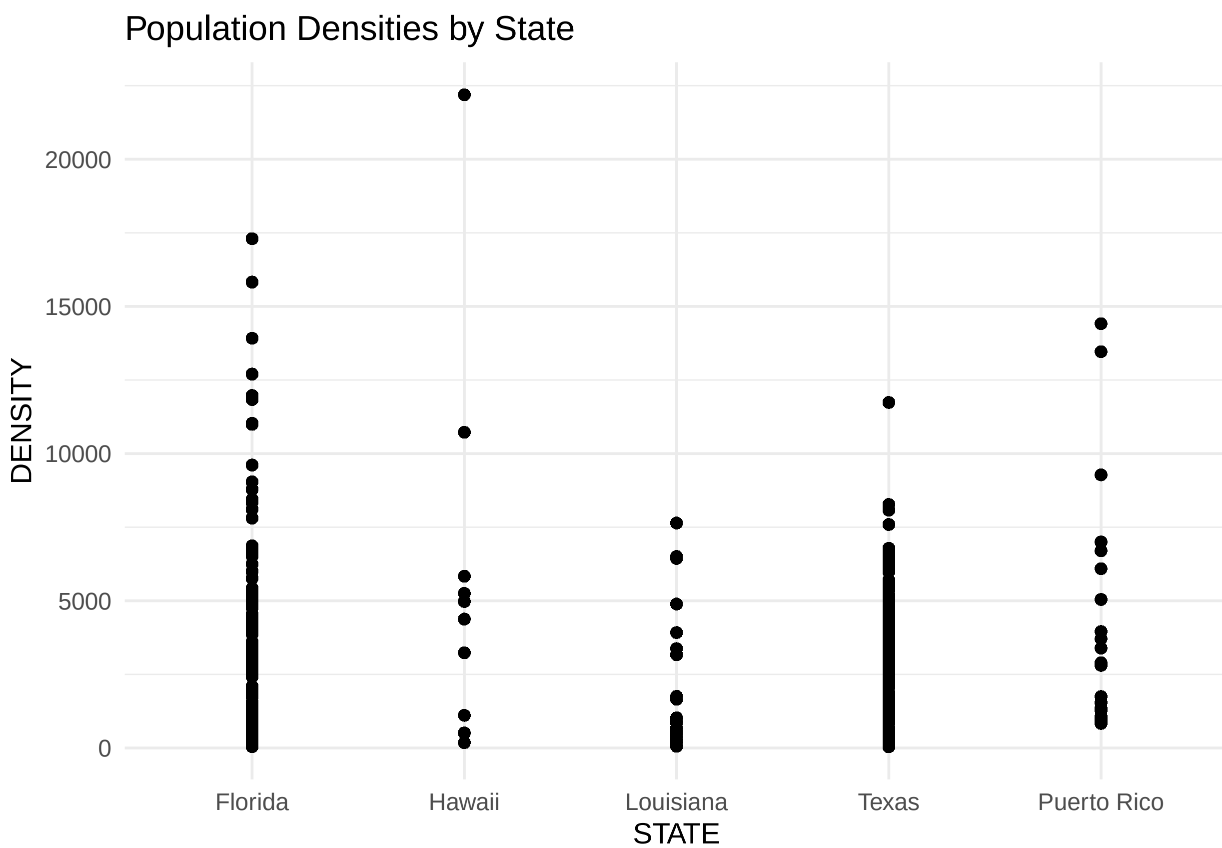


Fig. 5. Population Density By State (2019)

Density reports the average local population density among residents of each Public Use Microdata Area (PUMA) in persons per square mile. Specifically, “DENSITY” gives the population-weighted geometric mean of the population densities of census tracts in each PUMA (IPUMS). Some areas in Florida report higher average densities going up to 17,000. Honolulu appears to house a significant population of Hawaiians.

Income & Poverty

The data pertaining to income and poverty is sourced from the U.S. Census Bureau ACSDT1Y2019.B17020 (1-Year Estimate).

The table above represents people living below the poverty line in 2019 by age across the states.

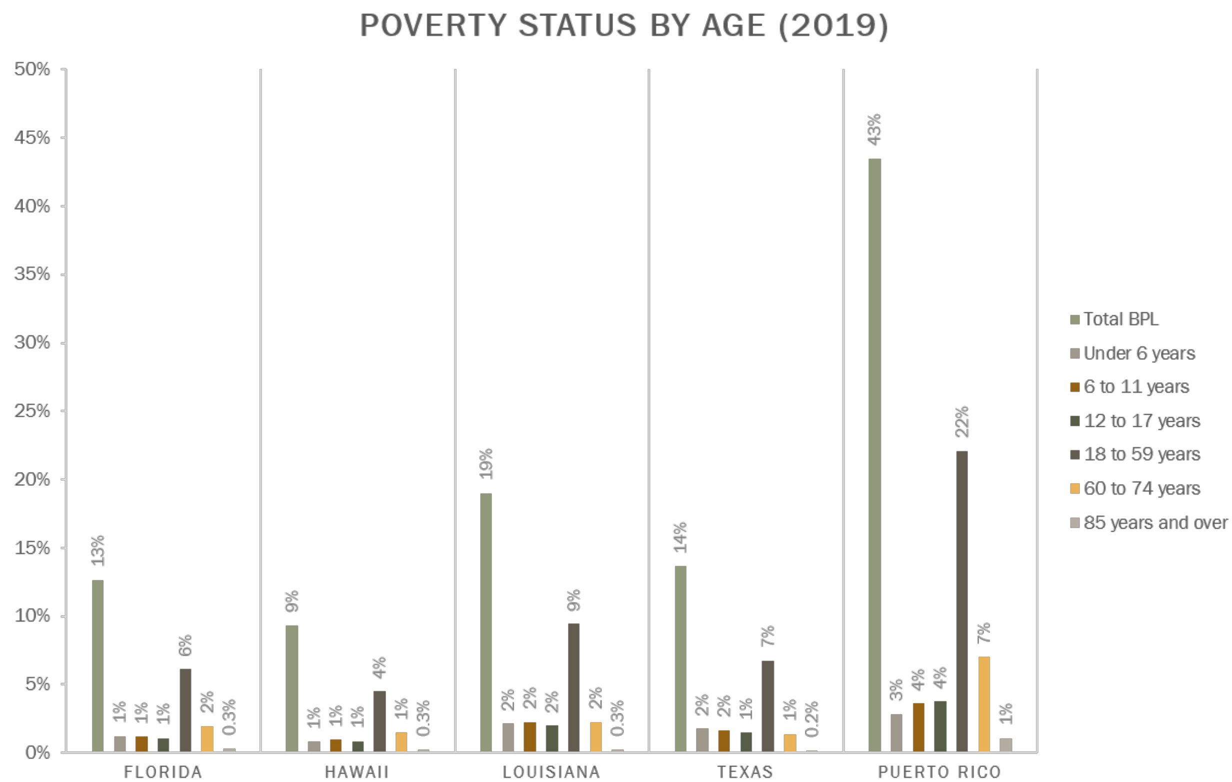


Fig. 5. Povery Status By Age (2019)

The chart above shows 43% of people for Puerto Rico living below the poverty line in 2018. The highest proportion of the population living below the poverty line is aged 18 to 59 years consistently across all the states. A significant number of the impoverished population in Texas comprises of teenagers.

Health Insurance

The data pertaining to health insurance coverage in the selected counties is sourced from the U.S. Census Bureau's American Community Survey (ACS) 2015-2019 5-year estimates. Some cases had missing data and thus had to be omitted from the analysis.However, majority of the selected counties is covered in the dataset below.

The chart below shows the health insurance coverage by age across the regions. The data represented is county level data aggregated to the state level. The chart shows the proportion of people with one or more types of health insurance coverage as compared to the percentage of population with no coverage. The insurance types covered in this dataset includes: 1. Employer-based Insurance 2. Direct Purchase Insurance 3. Medicare 4. Medicaid/Means-tested Public Coverage 5. Tricare/Military Health Coverage 6. VA Healthcare

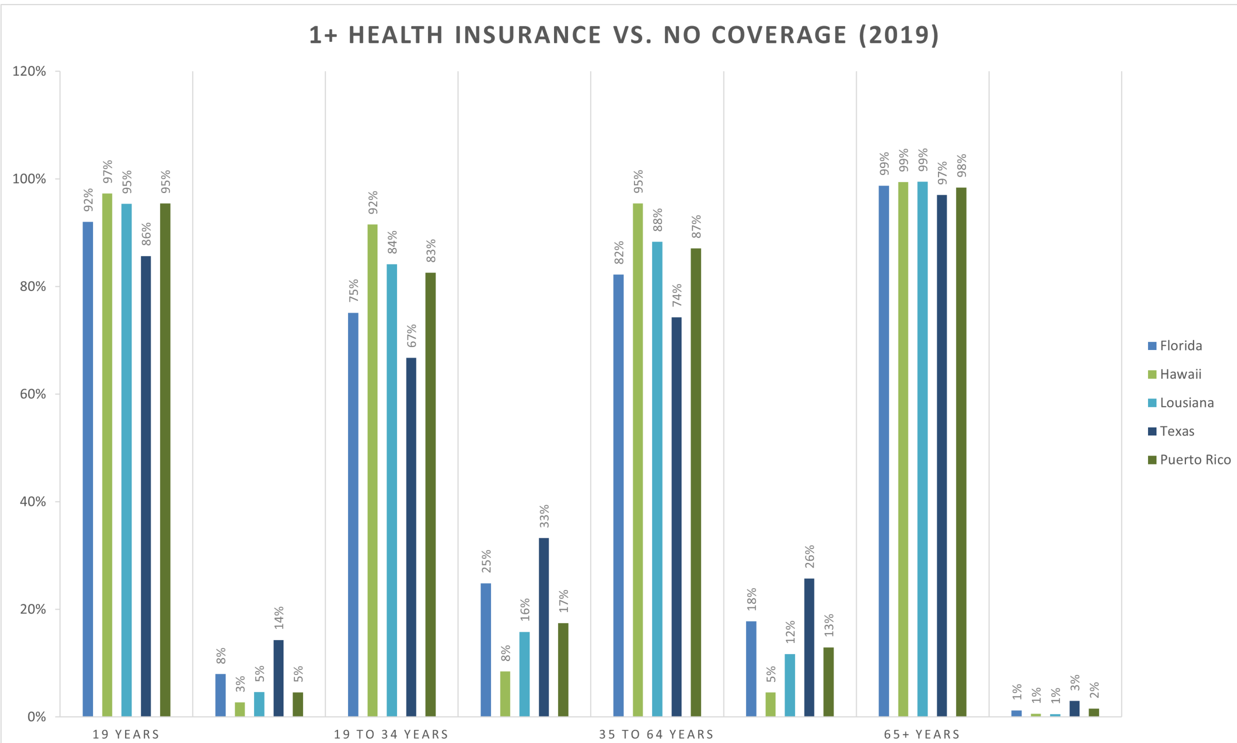


Fig. 6. Health Insurance Coverage By Age (2019)

It is observed that the proportion of people with no health coverage is highest in the age groups comprising of people aged 19 to 64. Children and senior citizens are relatively secure with a wide health insurance coverage. The proportion of uninsured people is consistently high across all age groups in the state of Texas. The state of Hawaii has the highest proportion of insured population.

Opportunity Mapping

There are several limitations to the opportunity mapping approach. Census tracts and other smaller administrative boundaries may not always match up with the boundaries of neighborhoods and communities. Two distinct neighborhoods of very unique character may fall within a single tract, which would mean those differences will not be captured (Stromberg, 2016). Analysis that overlooks nuanced factors and prudent considerations pertaining to these distinctions could foster inequity instead of creating opportunities for vulnerable communities, defeating the purpose for which this tool is designed.

The following variables are chosen for study:

- ID (Geographcial Identifier)
- ACSTOTPOP (Total Population)
- CANCER (Cancer Risk)
- RESP (Respiratory Hazard Risk)
- PTRAF (Traffic Proximity and Volume)
- PM25 (Particulate Matter)

We will also take an additional variable under consideration for this exercise. - DSLPM (Diesel Particulate Matter)

The 11 EJ Indexes as described by the Environmental Protection Agency (EPA) are:

1. National Scale Air Toxics Assessment Air Toxics Cancer Risk
2. National Scale Air Toxics Assessment Respiratory Hazard Index
3. National Scale Air Toxics Assessment Diesel PM (DPM)
4. Particulate Matter (PM2.5)
5. Ozone
6. Lead Paint Indicator
7. Traffic Proximity and Volume
8. Proximity to Risk Management Plan Sites
9. Proximity to Treatment Storage and Disposal Facilities
10. Proximity to National Priorities List Sites
11. Wastewater Discharge Indicator

Loading HUD LAI & EPA EJSCREEN Data

The HUD LAI data is obtained from ArcGIS Open Data and the EJSCREEN Data is retrieved from the EPA website.

We will select the following variables from the HUD LAI dataset:

- GEOID
- pct_transit_j2w
- median_gross_rent
- pct_hu_1_detached
- job_density_simple
- retail_density_simple
- median_commute

The Census API key is loaded here:

Table	Description
B01001	Age and Population
B02001	Race
B03001	Ethnicity
B05002	Foreign Born
B11001	Female Headed Household
B17001	Poverty Rate
B19013	Median Household Income
B25002	Residential Vacancy
B25003	Housing Tenure
B25077	Median Home Value
B25106	Housing Cost Burden

The following indicators have been selected for analysis:

Table	Label	Description
B01001	under18	Proportion of Population under 18
B01001	over65	Proportion of Population over 65
B01001	P_Female	Proportion of Population female
B01001	Pop	Total Population size
B02001	PWhite	Proportion Population White
B02001	PBlack	Proportion Population Black
B02001	PAIAN	Proportion Population AIAN
B02001	PAsian	Proportion Population Asian
B02001	PNonwhite	Proportion Population Nonwhite
B03001	PLatino	Proportion Population Latino Ethnicity (Of all Races)
B05002	PForeignborn	Proportion Population Foreign Born
B19013	MHHI	Median Household Income
B11001	P_FHHH	Proportion Female Headed Households
B17001	Pov	Proportion Households Below Poverty
B25003	P_Own	Proportion Owner Occupied Housing Units
B25077	MHV	Median Home Value
B25106	CostBurden	Housing Cost Burden
B25002	Rvac	Residential Vacancy Rate

```
## # A tibble: 11,954 x 10
##    GEOID       under18  over65   Pop P_Female PWhite  PBlack   PAIAN   PAsian
##    <chr>         <dbl>   <dbl> <dbl>    <dbl>  <dbl>   <dbl>   <dbl>    <dbl>
##  1 12086000211   0.190  0.131   2812    0.508  0.742  0.184   0        0.0434
##  2 12086000212   0.220  0.0822  4709    0.518  0.506  0.415   0        0.0187
##  3 12086000213   0.291  0.135   5005    0.512  0.466  0.441   0.0448   0.0318
##  4 12086000214   0.333  0.119   6754    0.566  0.600  0.247   0.0483   0.0524
##  5 12086000128   0.136  0.111   3021    0.439  0.947  0.0401  0        0
##  6 12086000130   0.102  0.343   2599    0.539  0.940  0.0292  0        0.0108
##  7 12086000129   0.119  0.481   2079    0.536  0.928  0       0        0.0375
##  8 12099980200  NA     NA          0   NA     NA     NA      NA       NA
##  9 12099980400  NA     NA          0   NA     NA     NA      NA       NA
## 10 12099004401   0.266  0.124   4215    0.479  0.789  0.152   0.0251   0.00427
## # ... with 11,944 more rows, and 1 more variable: PNonwhite <dbl>

## tibble [11,954 x 18] (S3: tbl_df/tbl/data.frame)
```

```
##  $ GEOID      : chr [1:11954] "12086000211" "12086000212" "12086000213" "12086000214" ...
##  $ under18    : num [1:11954] 0.19 0.22 0.291 0.333 0.136 ...
##  $ over65     : num [1:11954] 0.1312 0.0822 0.1355 0.1187 0.1109 ...
##  $ Pop        : num [1:11954] 2812 4709 5005 6754 3021 ...
##  $ P_Female   : num [1:11954] 0.508 0.518 0.512 0.566 0.439 ...
##  $ PWhite     : num [1:11954] 0.742 0.506 0.466 0.6 0.947 ...
##  $ PBlack     : num [1:11954] 0.1839 0.4147 0.4408 0.2474 0.0401 ...
##  $ PAIAN      : num [1:11954] 0 0 0.0448 0.0483 0 ...
##  $ PAsian     : num [1:11954] 0.0434 0.0187 0.0318 0.0524 0 ...
##  $ PNonwhite  : num [1:11954] 0.258 0.494 0.534 0.4 0.053 ...
##  $ PLatino    : num [1:11954] 0.532 0.475 0.174 0.396 0.655 ...
##  $ PForeignborn: num [1:11954] 0.496 0.599 0.458 0.423 0.492 ...
##  $ P_FHHH     : num [1:11954] 0.284 0.193 0.211 0.202 0.1 ...
##  $ Pov        : num [1:11954] 0.1337 0.2168 0.1297 0.1715 0.0649 ...
##  $ MHHI       : num [1:11954] 53533 33958 40250 39962 63889 ...
##  $ P_Own      : num [1:11954] 0.604 0.177 0.497 0.46 0.468 ...
##  $ MHV        : num [1:11954] 240400 179900 254900 147800 205900 ...
##  $ CostBurden : num [1:11954] 0.499 0.567 0.549 0.447 0.37 ...
```

Preparing the Datasets

Creating Standardized Scores

For this study, we are going to explore communities on the South Texas coastline:

FLORIDA: | Bay County | 12005 | | Brevard County | 12009 | | Broward County | 12011 | | Charlotte County | 12015 | | Citrus County | 12017 | | Collier County | 12021 | | Dixie County | 12029 | | Duval County | 12031 | | Escambia County | 12033 | | Flagler County | 12035 | | Franklin County | 12037 | | Gulf County | 12045 | | Hernando County | 12053 | | Hillsborough County | 12057 | | Indian River County | 12061 | | Jefferson County | 12065 | | Lee County | 12071 | | Levy County | 12075 | | Manatee County | 12081 | | Martin County | 12085 | | Miami-Dade County | 12086 | | Monroe County | 12087 | | Nassau County | 12089 | | Okaloosa County | 12091 | | Palm Beach County | 12099 | | Pasco County | 12101 | | Pinellas County | 12103 | | St. Johns County | 12109 | | St. Lucie County | 12111 | | Santa Rosa County | 12113 | | Sarasota County | 12115 | | Taylor County | 12123 | | Voluisa County | 12127 | | Wakulla County | 12129 | | Walton County | 12131 |

HAWAII: | Hawaii County | 15001 | | Honolulu County | 15003 | | Kalawao County | 15005 | | Kauai County | 15007 | | Maui County | 15009 |

LOUISIANA: | Acadia Parish | 22001 | | Ascension Parish | 22005 | | Assumption Parish | 22007 | | Calcasieu Parish | 22019 | | Cameron Parish | 22023 | | East Baton Rouge Parish | 22033 | | Iberia Parish | 22045 | | Iberville Parish | 22047 | | Jefferson Parish | 22051 | | Jefferson Davis Parish | 22053 | | Lafayette Parish | 22055 | | Lafrouche Parish | 22057 | | Livingston Parish | 22063 | | New Orleans Parish | 22071 | | Plaquemines Parish | 22075 | | St. Bernard Parish | 22087 | | St. Charles Parish | 22089 | | St. James Parish | 22093 | | St. John the Baptist Parish | 22095 | | St. Martin Parish | 22099 | | St. Mary Parish | 22101 | | St. Tammany Parish | 22103 | | Tangipahoa Parish | 22105 | | Terrebonne Parish | 22109 | | West Baton Rouge Parish | 22121 |

TEXAS: | Aransas County | 48007 | | Brazoria County | 48039 | | Calhoun County | 48057 | | Cameron County | 48061 | | Chambers County | 48071 | | Galveston County | 48167 | | Harris County | 48201 | | Jackson County | 48239 | | Jefferson County | 48245 | | Kenedy County | 48261 | | Kleberg County | 48273 | | Matagorda County | 48321 | | Nueces County | 48355 | | Orange County | 48361 | | Refugio County | 48391 | | San Patricio County | 48409 | | Willacy County | 48489 |

PUERTO RICO: | Arecibo Municipality | 72013 | | Barcelonetta Municipality | 72017 | | Bayamón Municipality | 72021 | | Carolina Municipality | 72031 | | Ceiba Municipality | 72037 | | Dorado Municipality | 72051 | | Fajardo Municipality | 72053 | | Guaynabo Municipality | 72061 | | Humacao Municipality | 72069 | | Loíza Municipality | 72087 | | Luquillo Municipality | 72089 | | Naguabo Municipality | 72103 | | Río Grande Municipality | 72119 | | San Juan Municipality | 72127 | | Toa Baja Municipality | 72137 | | Vega Baja Municipality | 72145 |

```
## # A tibble: 1 x 29
##   under18 over65   Pop P_Female PWhite PBlack   PAIAN PAsian PNonwhite PLatino
##     <dbl>  <dbl> <dbl>    <dbl>  <dbl>  <dbl>   <dbl>  <dbl>     <dbl>   <dbl>
## 1   0.204  0.195 4668.    0.511  0.695  0.172 0.00334 0.0461     0.305   0.304
## # ... with 19 more variables: PForeignborn <dbl>, P_FHHH <dbl>, Pov <dbl>,
## #   MHHI <dbl>, P_Own <dbl>, MHV <dbl>, CostBurden <dbl>, CANCER <dbl>,
## #   RESP <dbl>, PTRAF <dbl>, PM25 <dbl>, DSLPM <dbl>, STUSAB <dbl>,
## #   pct_transit_j2w <dbl>, median_gross_rent <dbl>, pct_hu_1_detached <dbl>,
## #   job_density_simple <dbl>, retail_density_simple <dbl>, median_commute <dbl>
```

```
## # A tibble: 98 x 30
##    `substr(GEOID, 0~ under18 over65   Pop P_Female PWhite PBlack   PAIAN  PAsian
##  * <chr>               <dbl>  <dbl> <dbl>    <dbl>  <dbl>  <dbl>   <dbl>   <dbl>
##  1 12005               0.202  0.180 4140.    0.503  0.796 0.125  3.68e-3 0.0228
```

```
##  2 12009             0.175  0.243 5136.    0.510  0.828 0.0971 3.09e-3 0.0231
##  3 12011             0.198  0.183 5321.    0.510  0.635 0.267  2.39e-3 0.0315
##  4 12015             0.114  0.420 4643.    0.512  0.909 0.0491 2.85e-3 0.0134
##  5 12017             0.146  0.358 5185.    0.514  0.936 0.0255 3.31e-3 0.0141
##  6 12021             0.144  0.373 5020.    0.513  0.896 0.0637 2.61e-3 0.0132
##  7 12029             0.187  0.224 4147.    0.440  0.858 0.0917 1.20e-4 0.00238
##  8 12031             0.225  0.143 5380.    0.516  0.589 0.317  2.80e-3 0.0380
##  9 12033             0.208  0.171 4354.    0.503  0.659 0.248  3.79e-3 0.0258
## 10 12035             0.157  0.326 5229.    0.522  0.841 0.0894 2.97e-3 0.0250
## # ... with 88 more rows, and 21 more variables: PNonwhite <dbl>, PLatino <dbl>,
## #   PForeignborn <dbl>, P_FHHH <dbl>, Pov <dbl>, MHHI <dbl>, P_Own <dbl>,
## #   MHV <dbl>, CostBurden <dbl>, CANCER <dbl>, RESP <dbl>, PTRAF <dbl>,
## #   PM25 <dbl>, DSLPM <dbl>, STUSAB <dbl>, pct_transit_j2w <dbl>,
## #   median_gross_rent <dbl>, pct_hu_1_detached <dbl>, job_density_simple <dbl>,
## #   retail_density_simple <dbl>, median_commute <dbl>
```

Variable	Description	Relationship to Opportunity	Category
under18	Proportion of Population under 18	Negative	Demographic Structure
over65	Proportion of Population over 65	Negative	Demographic Structure
PNonwhite	Proportion Population Nonwhite	Negative	Demographic Structure
PForeignborn	Proportion Population Foreign Born	Negative	Demographic Structure
MHHI	Median Household Income	Positive	Employment and Economy
P_FHHH	Proportion Female Headed Households	Negative	Demographic Structure
Pov	Proportion Households Below Poverty	Negative	Demographic Structure
P_Own	Proportion Owner Occupied Housing Units	Positive	Housing
MHV	Median Home Value	Positive	Housing
CostBurden	Housing Cost Burden	Negative	Housing
CANCER	Cancer Risk Index	Negative	Environmental Health
RESP	Respiratory Hazard Index	Negative	Environmental Health
PTRAF	Traffic Proximity Index	Negative	Environmental Health
PM25	Particulate Matter Index	Negative	Environmental Health
pct_transit_j2w	Commuting by Public Transportation	Positive	Transportation
median_gross_rent	Median Gross Rent	Negative	Housing
pct_hu_1_detached	Detached Housing Units	Positive	Housing
job_density_simple	Job Density	Positive	Employment and Economy
retail_density_simple	Retail Density	Positive	Employment and Economy

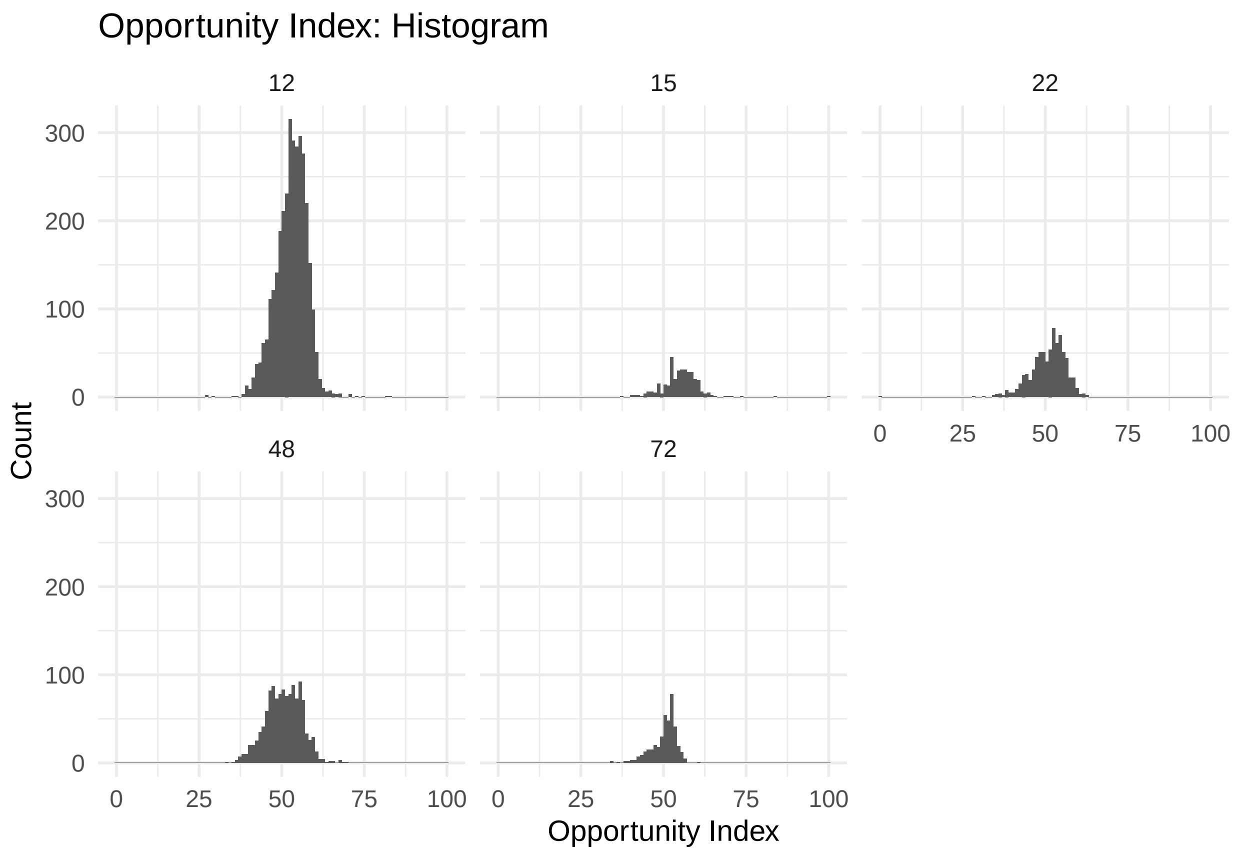
Variable	Description	Relationship to Opportunity	Category
median_commute	Median Commute Time	Negative	Transportation

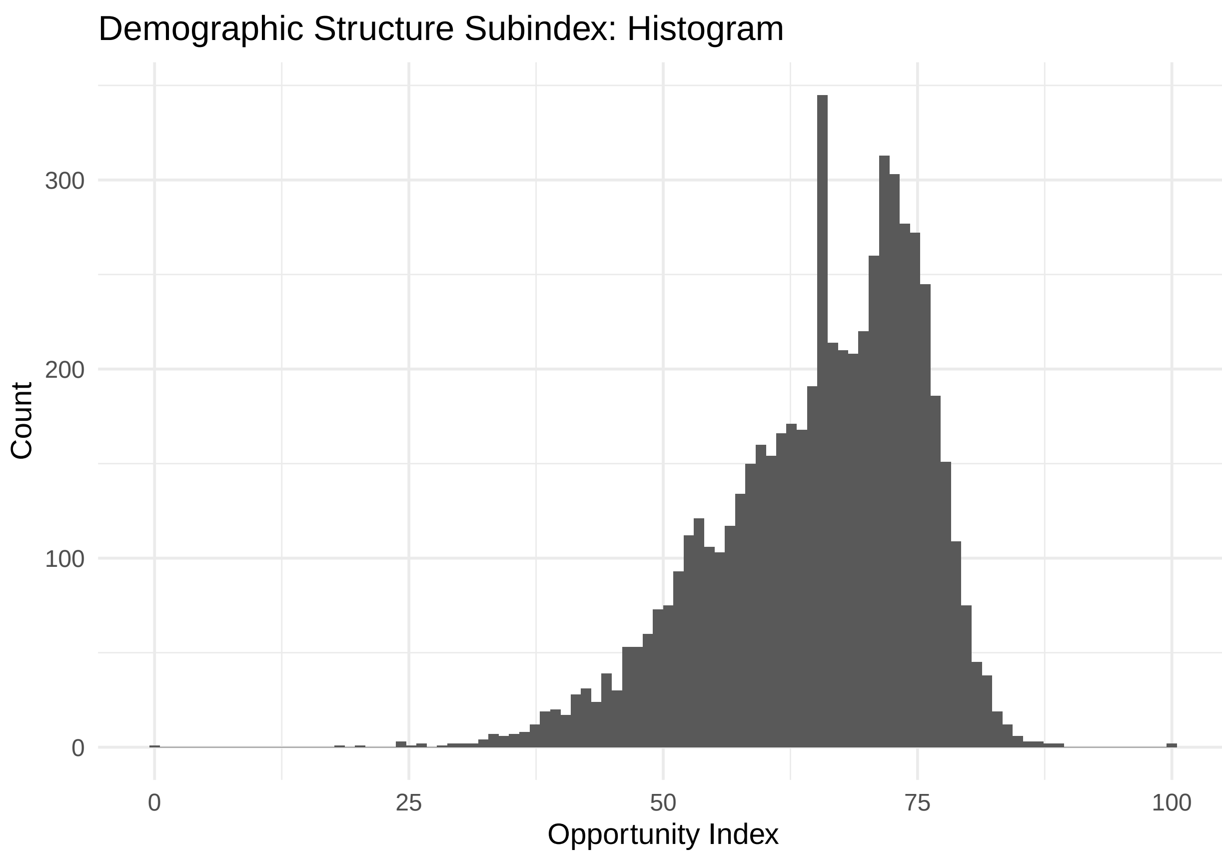
```
##     dem_index          emp_index          hou_index           env_index       
##  Min.   :-17.7462   Min.   :-2.4604   Min.   :-13.1254   Min.   :-50.2847  
##  1st Qu.: -1.7037   1st Qu.:-0.9016   1st Qu.: -1.4915   1st Qu.: -1.2102  
##  Median :  0.4263   Median :-0.3361   Median :  0.2755   Median :  0.2839  
##  Mean   :  0.0000   Mean   : 0.0000   Mean   :  0.0000   Mean   :  0.0000  
##  3rd Qu.:  2.0784   3rd Qu.: 0.3638   3rd Qu.:  1.8086   3rd Qu.:  1.6520  
##  Max.   :  9.4207   Max.   :50.6726   Max.   : 11.3017   Max.   :  4.6217  
##    tra_index           tot_index       
##  Min.   :-14.8648   Min.   :-56.4358  
##  1st Qu.: -0.6193   1st Qu.: -3.3991  
##  Median :  0.0000   Median :  0.3491  
##  Mean   :  0.0000   Mean   :  0.0000  
##  3rd Qu.:  0.4604   3rd Qu.:  3.7332  
##  Max.   :  9.2975   Max.   : 51.8076
```

The results that are obtained are scaled to reflect a range of 0-100.

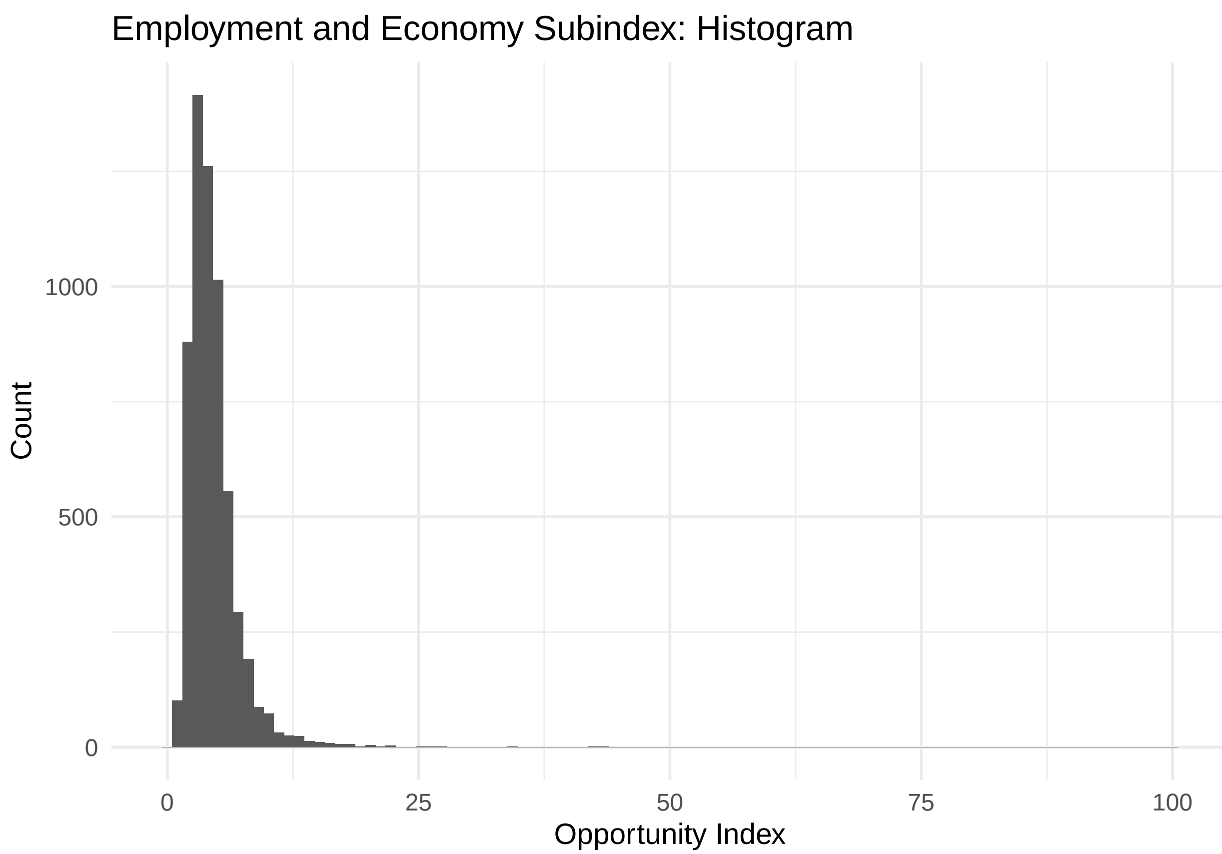
```
##     dem_index        emp_index          hou_index         env_index     
##  Min.   :  0.00   Min.   :  0.000   Min.   :  0.00   Min.   :  0.00  
##  1st Qu.: 59.05   1st Qu.:  2.934   1st Qu.: 47.63   1st Qu.: 89.38  
##  Median : 66.89   Median :  3.998   Median : 54.86   Median : 92.10  
##  Mean   : 65.32   Mean   :  4.631   Mean   : 53.73   Mean   : 91.58  
##  3rd Qu.: 72.97   3rd Qu.:  5.315   3rd Qu.: 61.14   3rd Qu.: 94.59  
##  Max.   :100.00   Max.   :100.000   Max.   :100.00   Max.   :100.00  
##    tra_index        tot_index     
##  Min.   :  0.00   Min.   :  0.00  
##  1st Qu.: 58.96   1st Qu.: 49.00  
##  Median : 61.52   Median : 52.46  
##  Mean   : 61.52   Mean   : 52.14  
##  3rd Qu.: 63.43   3rd Qu.: 55.59  
##  Max.   :100.00   Max.   :100.00
```

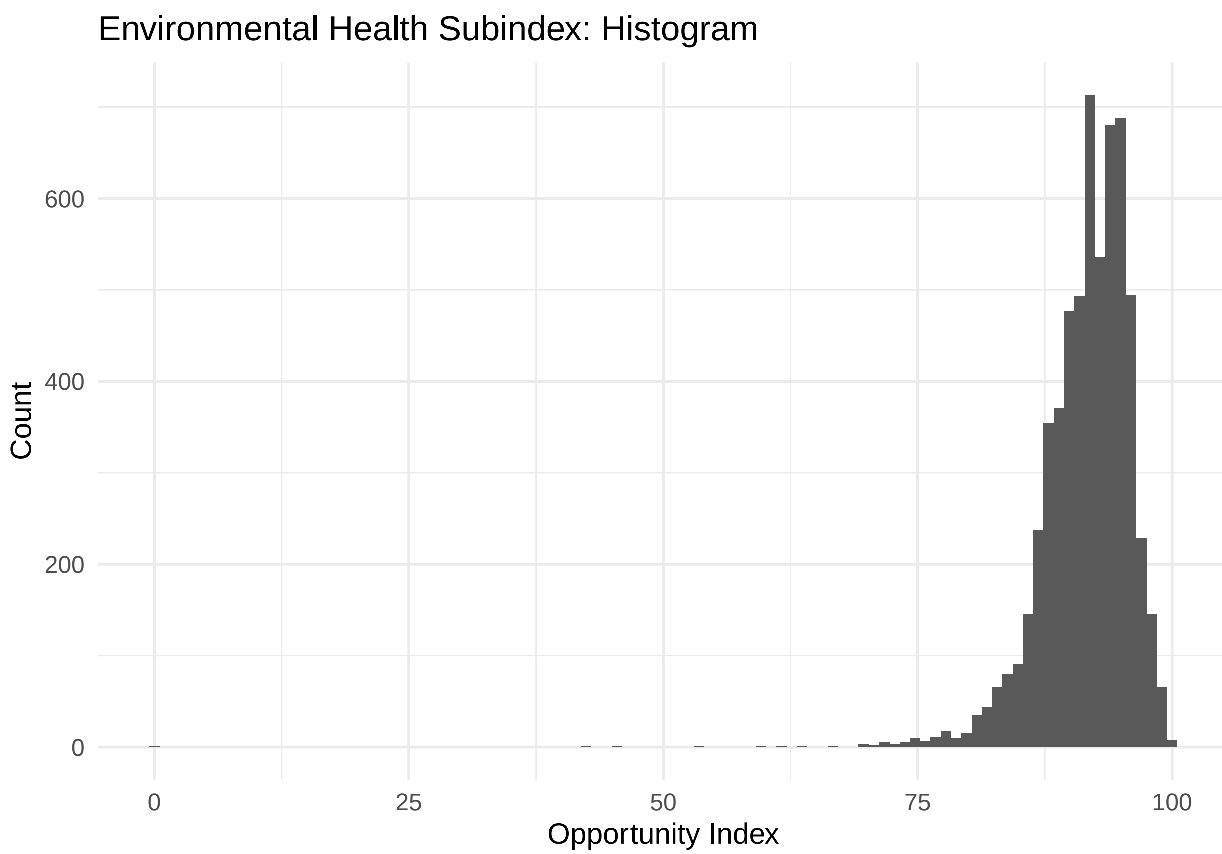
Visualizing Index Values



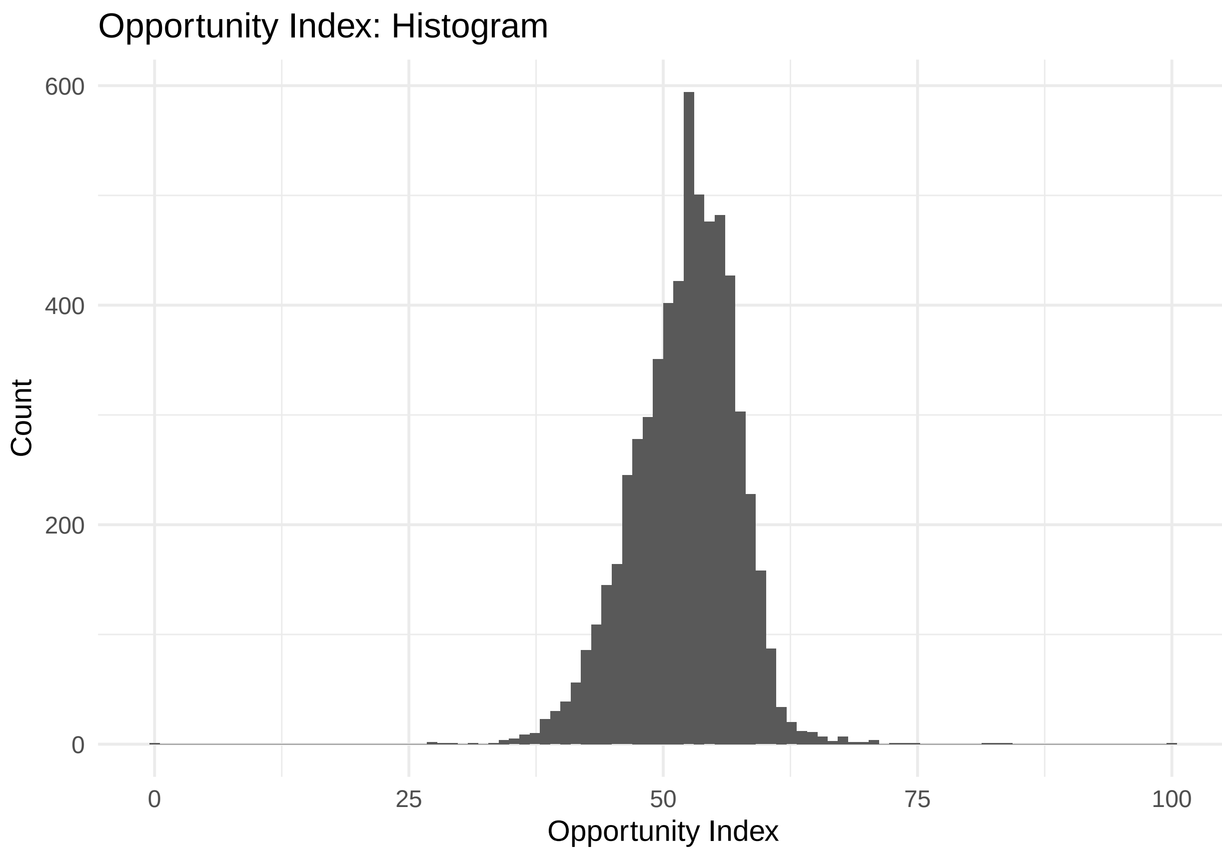


Demographic Structure Subindex: Histogram
300
200
100
0
Count
0
25
50
75
100
Opportunity Index


Employment and Economy Subindex: Histogram
Count
1000
500
0
0
25
50
75
100
Opportunity Index

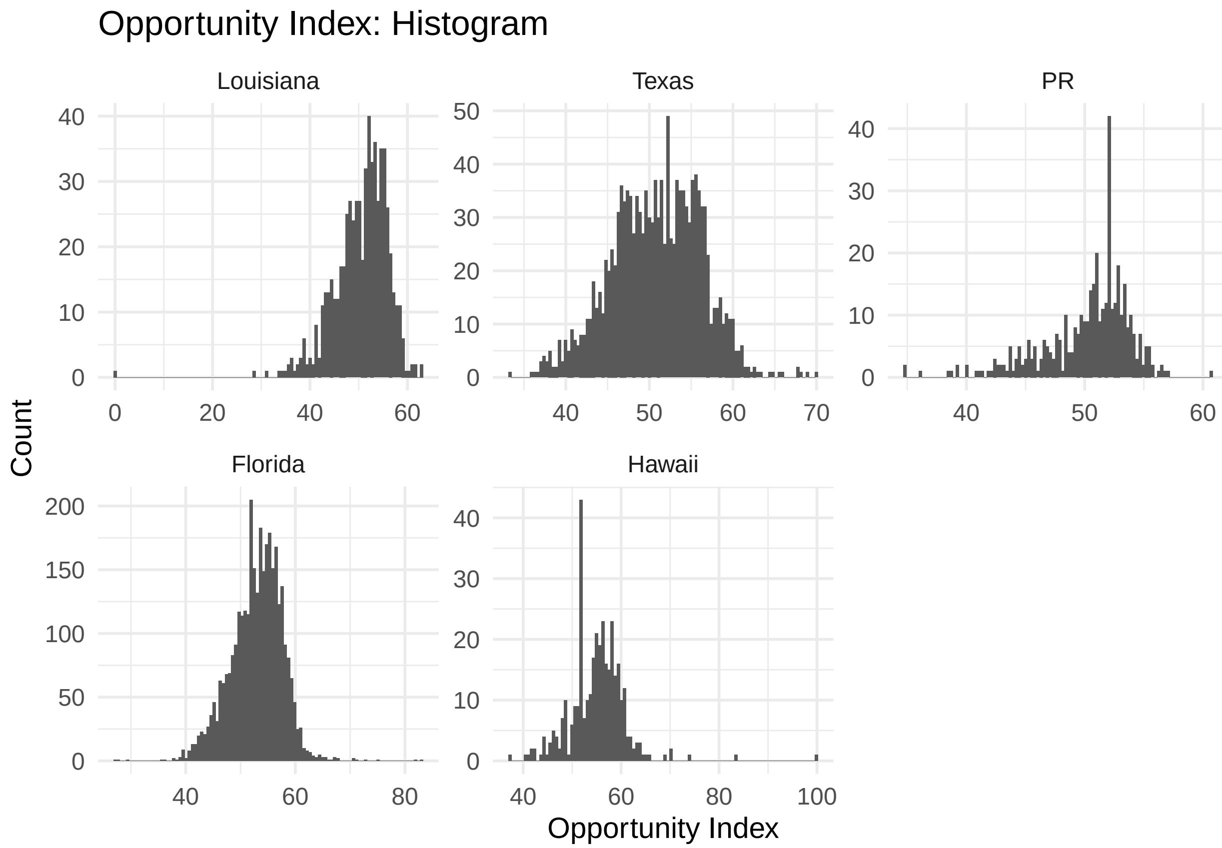

Environmental Health Subindex: Histogram
Count
600
400
200
0
0
25
50
75
100
Opportunity Index

Demographics by Opportunity Levels

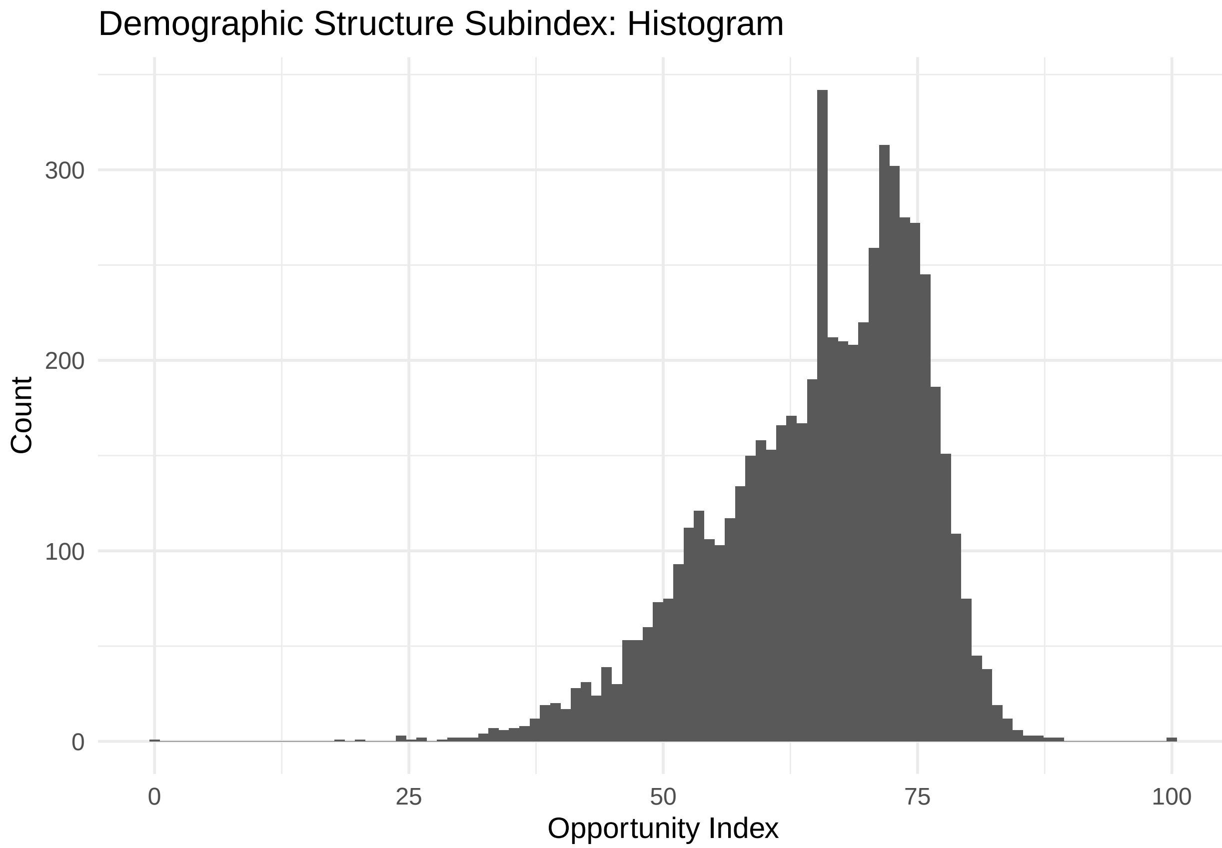


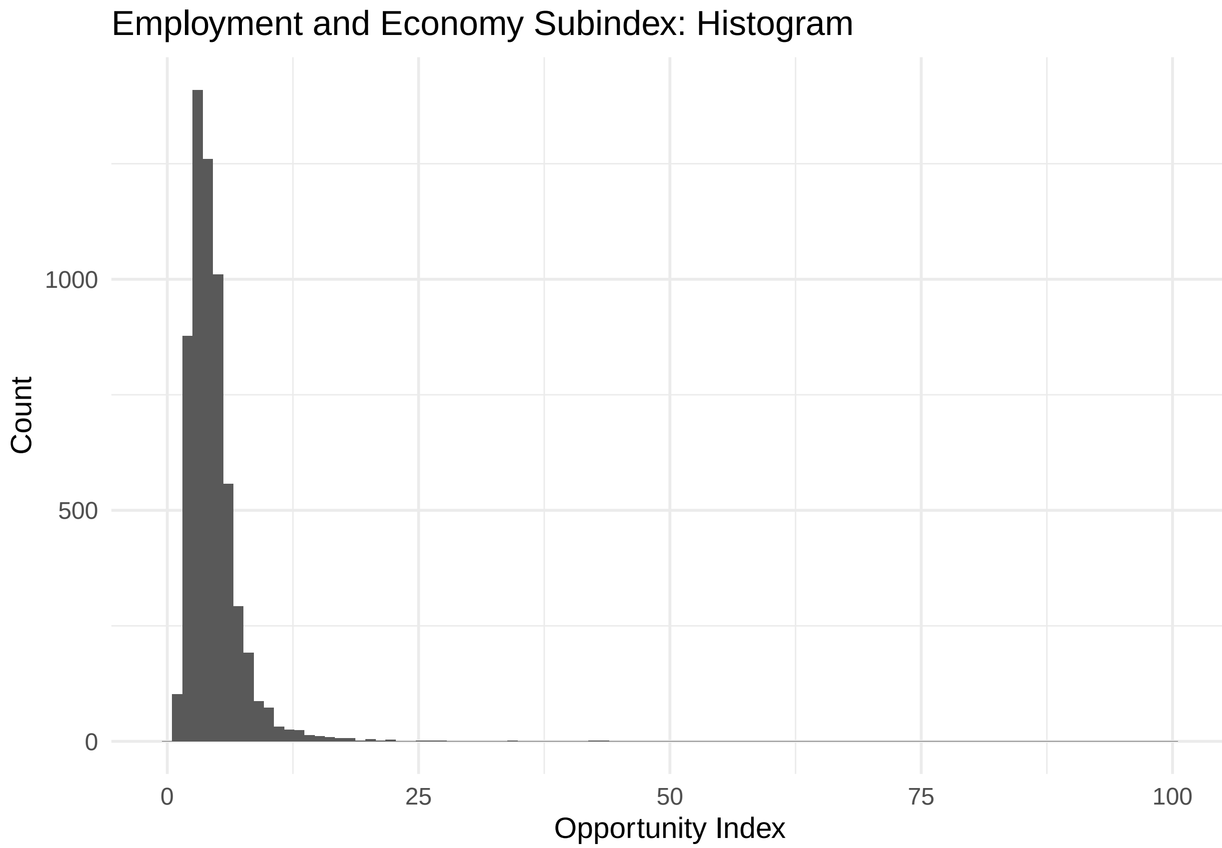
Divided by Counties

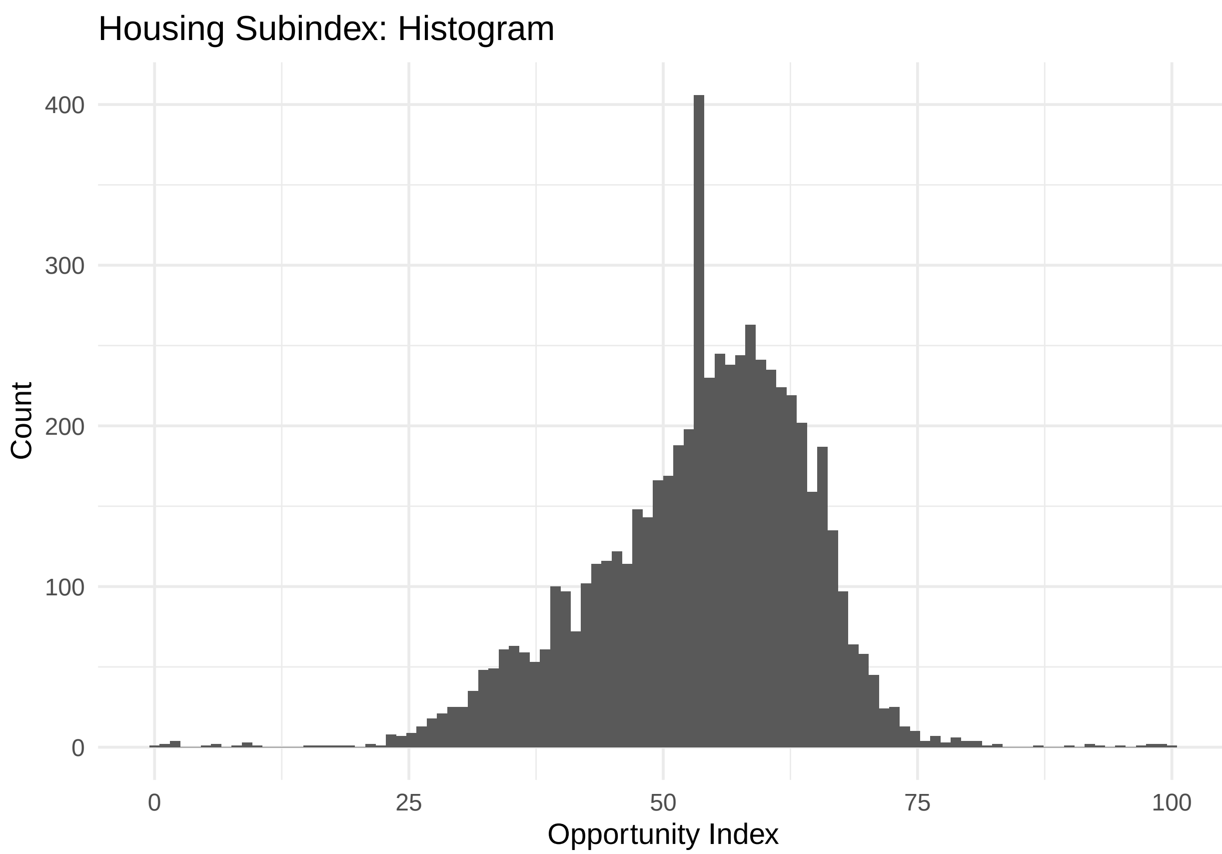
```
## Warning: Problem with ‘mutate()‘ input ‘State‘.
## i Unknown levels in ‘f‘: NA
## i Input ‘State‘ is ‘fct_collapse(...)‘.
```



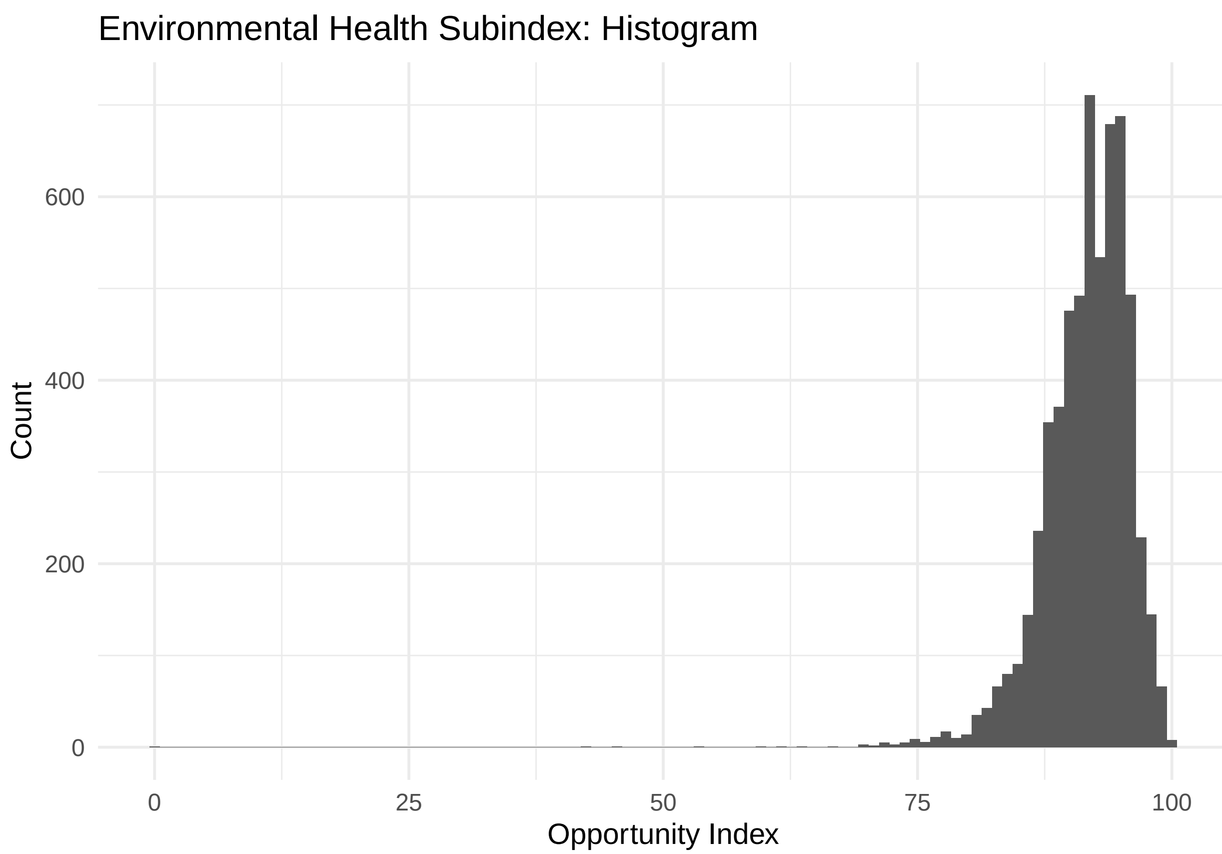
Counties/Municipalities in Puerto Rico and Texas have the highest spread of opportunity.Hawaii appears to have a tighter spread across its counties. The opportunity indexes are not disparate across the five cases. Thus, a distributive multi-front investment approach across the coastal states would enhance resilience capacity more effectively than a concentrated investment in individual communities.

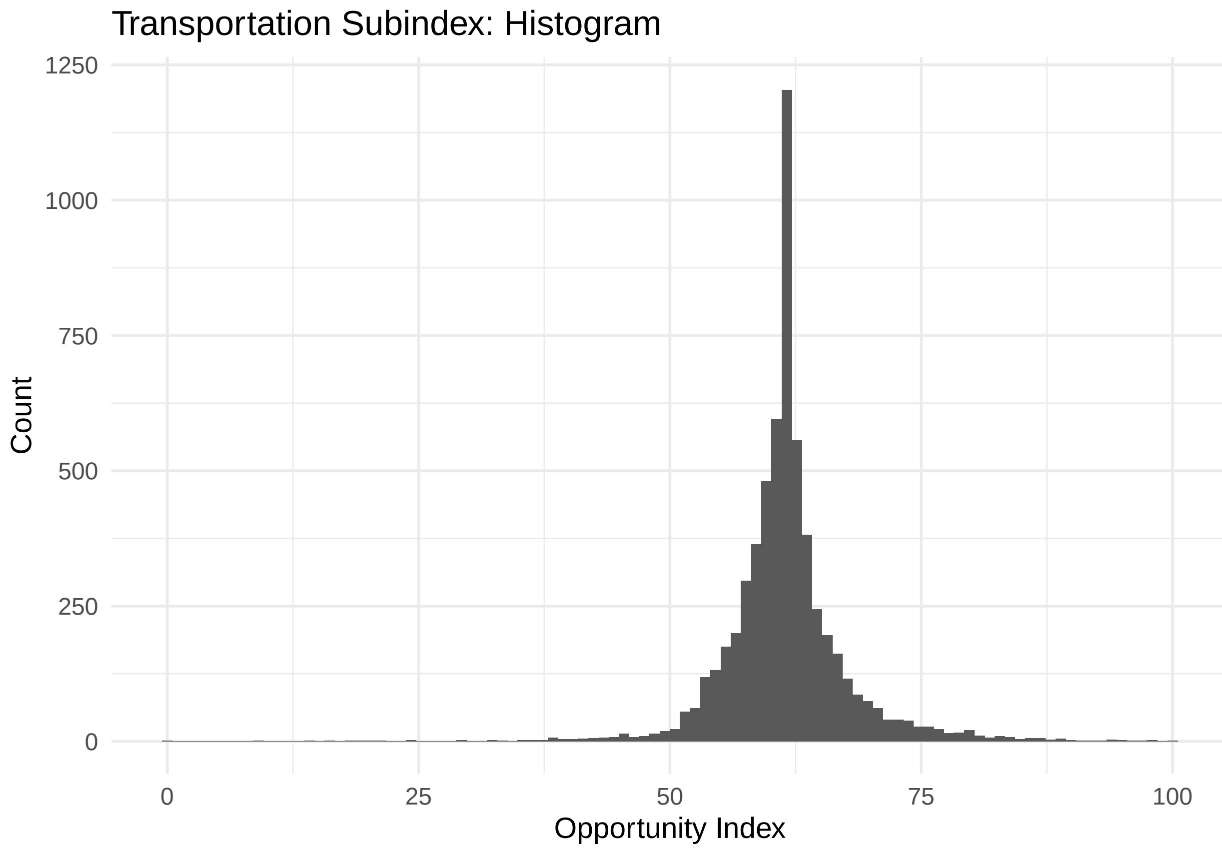

Demographic Structure Subindex: Histogram
Count
300
200
100
0
0
25
50
75
100
Opportunity Index


Employment and Economy Subindex: Histogram
Count
1000
500
0
0
25
50
75
100
Opportunity Index

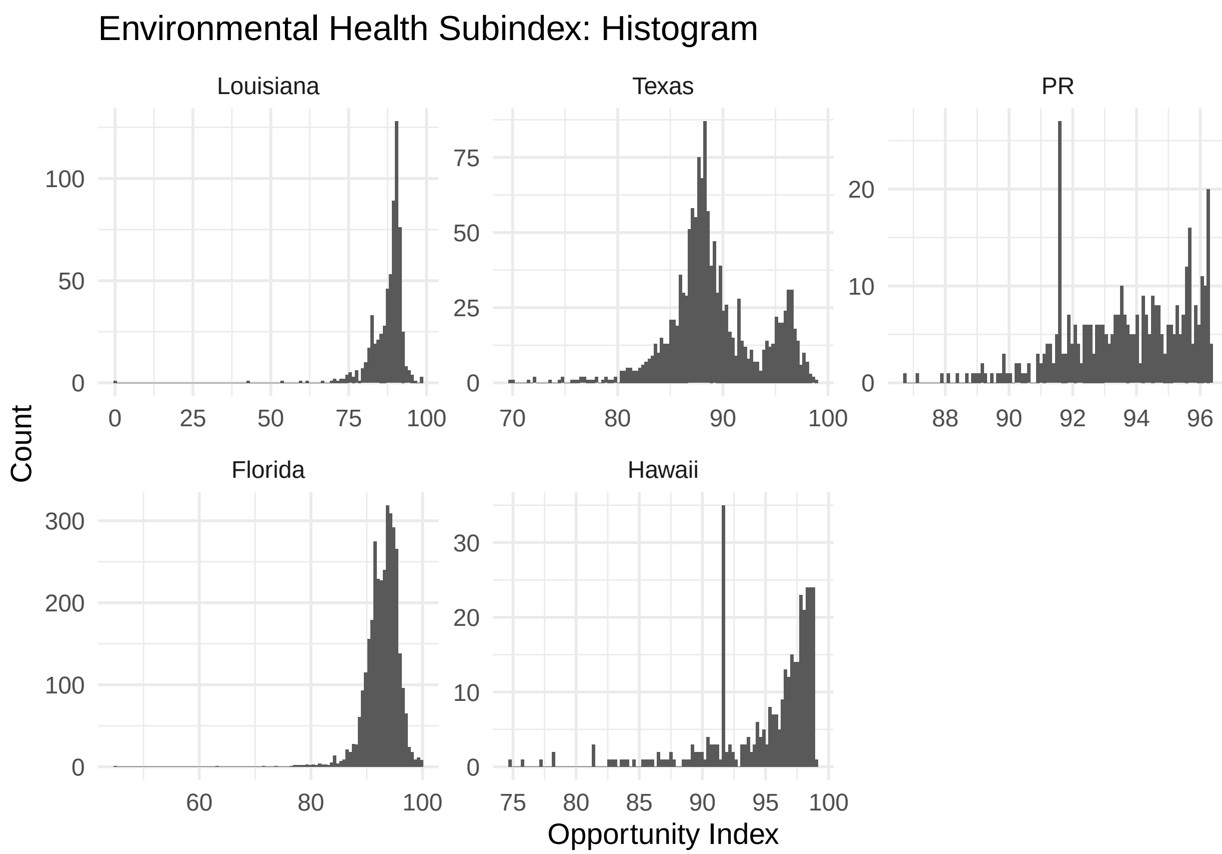


Housing Subindex: Histogram
400
300
200
100
0
Count
0
25
50
75
100
Opportunity Index


Environmental Health Subindex: Histogram
Count
600
400
200
0
0
25
50
75
100
Opportunity Index



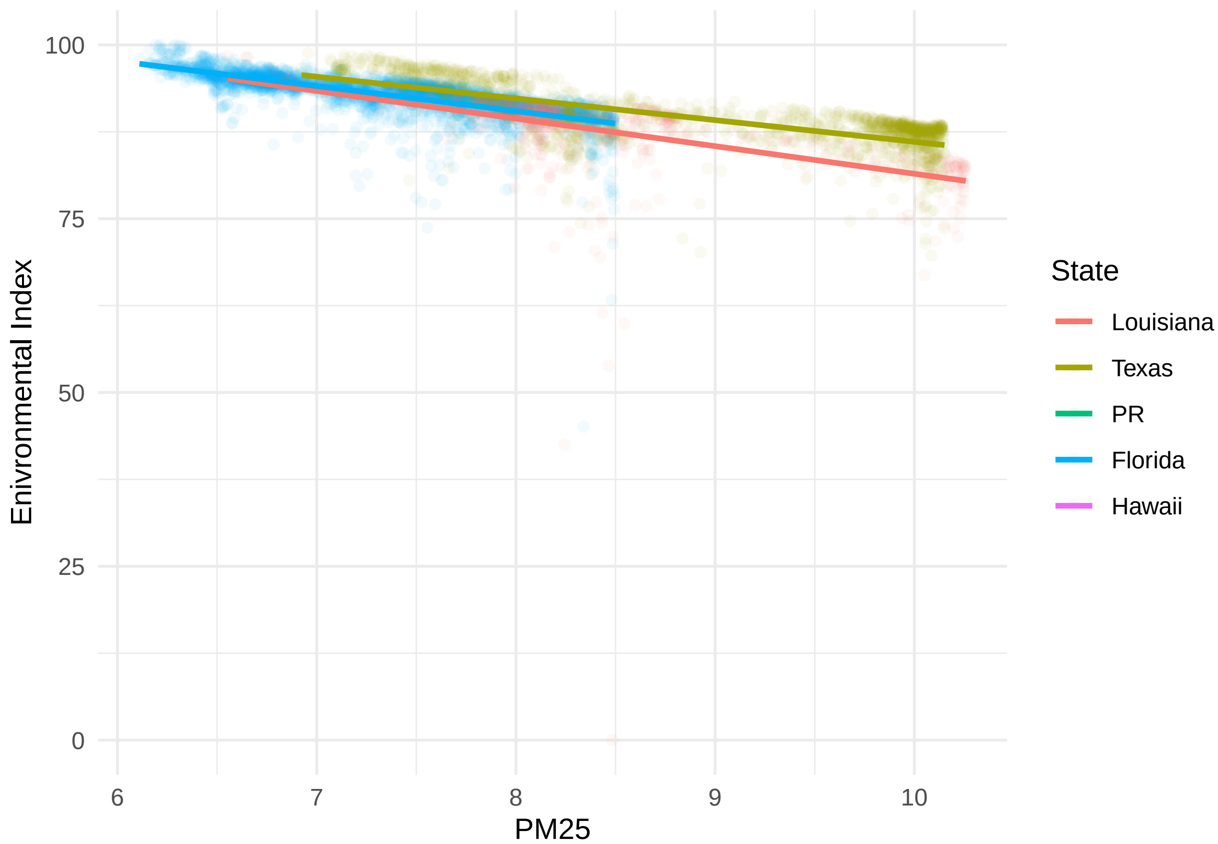
Transportation Subindex: Histogram
1250
1000
750
500
250
0
Count
0
25
50
75
100
Opportunity Index



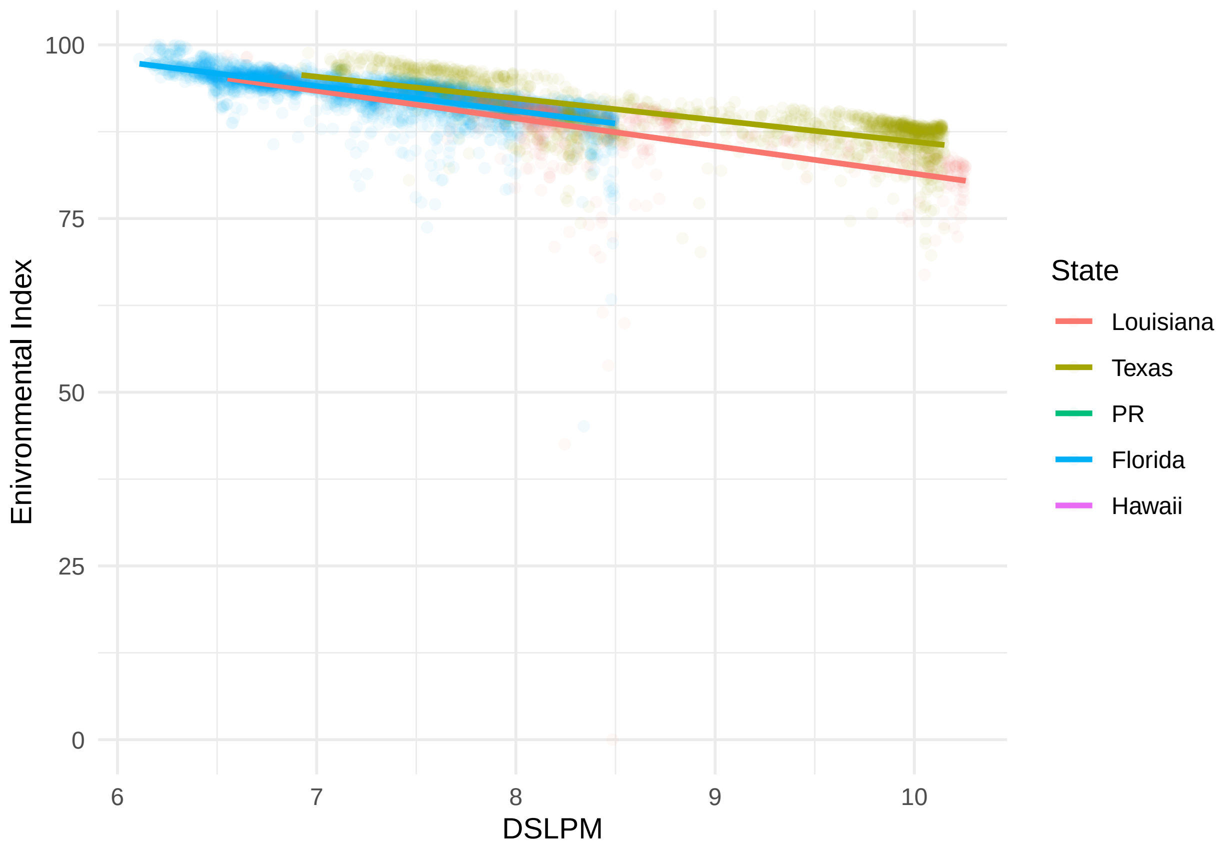
Puerto Rico and Hawaii have similar environmental health subindexes which ranges from 88 to 96. Counties in Florida and Texas are spread across 80 to 100 on the ENV scale. The looser spread in these two states would indicate more opportunity in these regions.

The charts below explore the relationship between PM25 and DSLPM (Diesel) with the environmental subindex.

```
## 'geom_smooth()' using formula 'y ~ x'
```




```
## ‘geom_smooth()‘ using formula ’y ~ x’
```



The two charts above show that the environmental subindex gradually subsides with an increase in Suspended Particulate Matter and Diesel Particulate Matter exposure. This relationship is detrimental particularly for the state of Louisiana.

Policy Recommendations & Future Discussion

Place profiling helps us understand the demographic mix and economic status of the communities. Opportunity mapping will help guide investments to communities where it is needed most. The combined analysis of place profile and opportunity zone mapping helps us understand how vulnerable certain communities are compared to others. Investment can be directed towards programs boosting community resilience, coastal zone property buy-outs, social capital building, and infrastructure development such as hard and soft coastal engineering measures.

This report recommends a combined investment strategy across the four states and the U.S. territory of Puerto Rico as opposed to a concentrated effort in particular regions. Statewide funds can be allocated on the basis of county level opportunity zone mapping to ensure an equitable distribution. Well-performing counties can be provided with incentives to promote a commited effort to climate resilience.

This report does not compare the coastal counties with counties located further inland. This analysis can be undertaken in the future for a more robust understanding of relative vulnerability across communities.

References

Image 1: https://www.nytimes.com/interactive/2017/08/24/us/hurricane-harvey-texas.html

Image 2: https://www.nytimes.com/interactive/2017/09/18/world/americas/hurricane-maria-tracking-map.html

Baldwin, Sarah Lynch (2018). Begnaud, David. "Hurricane Maria caused an estimated 2,975 deaths in Puerto Rico, new study finds". CBS News. Archived from the original on August 28, 2018. Retrieved August 28, 2018.

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- U.S. Census Bureau's American Community Survey (ACS) 2015-2019 5-year estimates, Table(s) B27010