Homework 1: Map Making Practice

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Introduction: Exploring Environmental (In)justice

Environmental justice examines whether environmental burdens and benefits are distributed equitably across different communities. This analysis focuses on Puerto Rico's metropolitan area using the U.S. EPA's EJScreen (2023) dataset to explore disparities in exposure to toxic air pollution.

The first variable, `P_LOWINCPCT`, represents the percentile rank of low-income populations across census block groups, where lower values indicate less economic vulnerability. The second variable, `D2_CANCER`, is the Air Toxics Cancer Risk Environmental Justice Index (EJ Index), which combines estimates of exposure to air toxics with demographic factors of vulnerability. By mapping both variables, this project seeks to identify whether low-income communities in Puerto Rico's metropolitan area face disproportionate cancer risks associated with toxic air pollutants.

Data

```
# Load relevant packages
library(sf)
library(here)
library(tidyverse)
library(tmap)
library(tinytex)
```

```
# Read in the geodatabase of the EJScreen data at the Census Block Group level
ejscreen <- st_read(here("data", "ejscreen",
                "EJSCREEN_2023_BG_StatePct_with_AS_CNMI_GU_VI.gdb"))
```

```
Reading layer `EJSCREEN_StatePctiles_with_AS_CNMI_GU_VI' from data source
  `C:\Documents\MEDS\EDS223\EDS223-2025-Homework-
1\data\ejscreen\EJSCREEN_2023_BG_StatePct_with_AS_CNMI_GU_VI.gdb'
  using driver `OpenFileGDB'
Simple feature collection with 243021 features and 223 fields
Geometry type: MULTIPOLYGON
Dimension:     XY
Bounding box:  xmin: -19951910 ymin: -1617130 xmax: 16259830 ymax: 11554350
Projected CRS: WGS 84 / Pseudo-Mercator
```

Methods

To explore environmental justice in the Metropolitan area of Puerto Rico, the dataset was filtered to the EJScreen dataset for block groups within the relevant municipalities (San Juan, Cataño, Bayamón, Carolina, Guaynabo, and Trujillo Alto) and selected the variables related to low income block groups and Cancer Risk to Air Toxics. I then mapped these indicators to visualize spatial patterns of environmental health vulnerability.

```
#Filter the dataset into metropolitan municipalities: San Juan, Cataño, Bayamón, Carolina, Guaynal

puerto_rico <- ejscreen %>%
  filter(ST_ABBREV == "PR")

metro <- puerto_rico %>%
  filter(CNTY_NAME %in% c("San Juan Municipio",
                                          "Cataño Municipio",
                                          "Bayamón Municipio",
                                          "Carolina Municipio",
                                          "Guaynabo Municipio",
                                          "Trujillo Alto Municipio"))
```

Data Exploration

```
  #Summary Statistics: Percentile of low income percentage
summary(metro$P_LOWINCPCT)
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   0.00   12.00   29.00   36.38   56.00   97.00
```

```
  #summary Statistics: Air toxics cancer risk EJ Index
summary(metro$D2_CANCER)
```

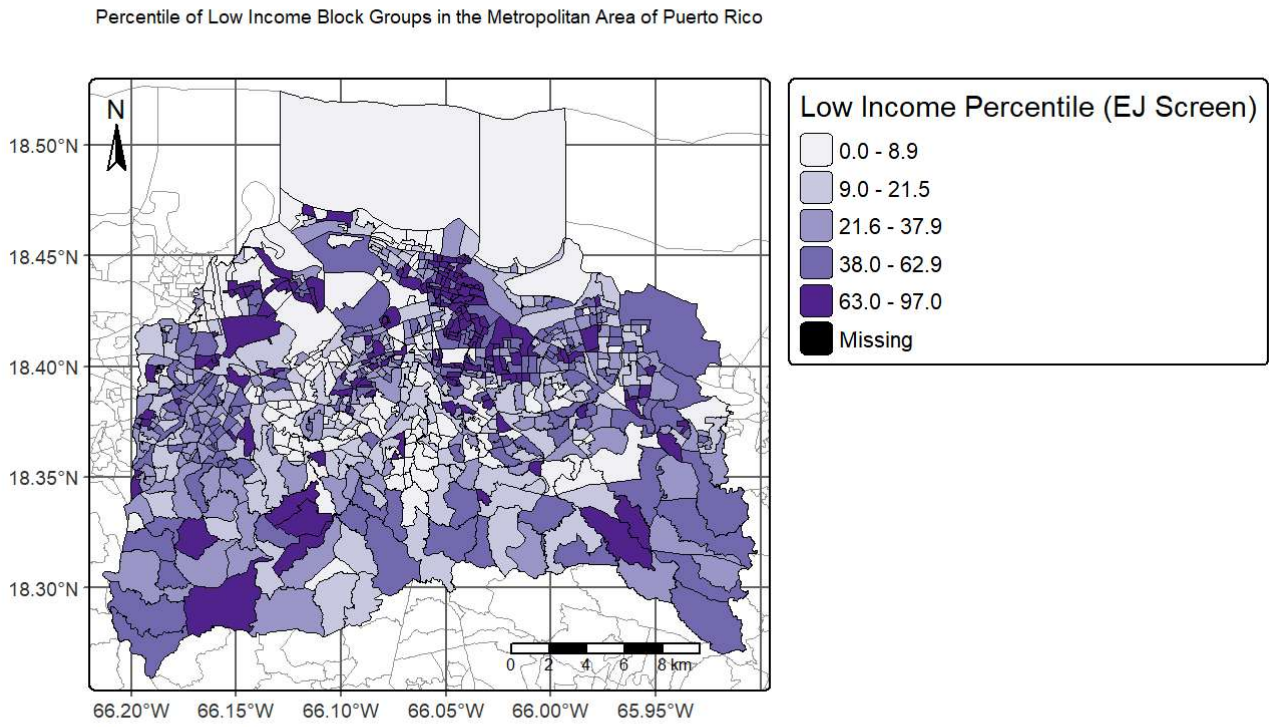
```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
   0.00   10.77   12.24   11.89   13.31   77.22       9
```

Map 1: Percentile Ranking of Low Income Percentages in the Metropolitan Area of Puerto Rico

```
tmap_mode("plot")
```

```
#Show outline of the island, but with the extent of the study area
tm_shape(puerto_rico, bbox = st_bbox(metro)) +

  #Show borders of puerto rico
  tm_borders(col = "gray60", lwd = 0.5) +
```

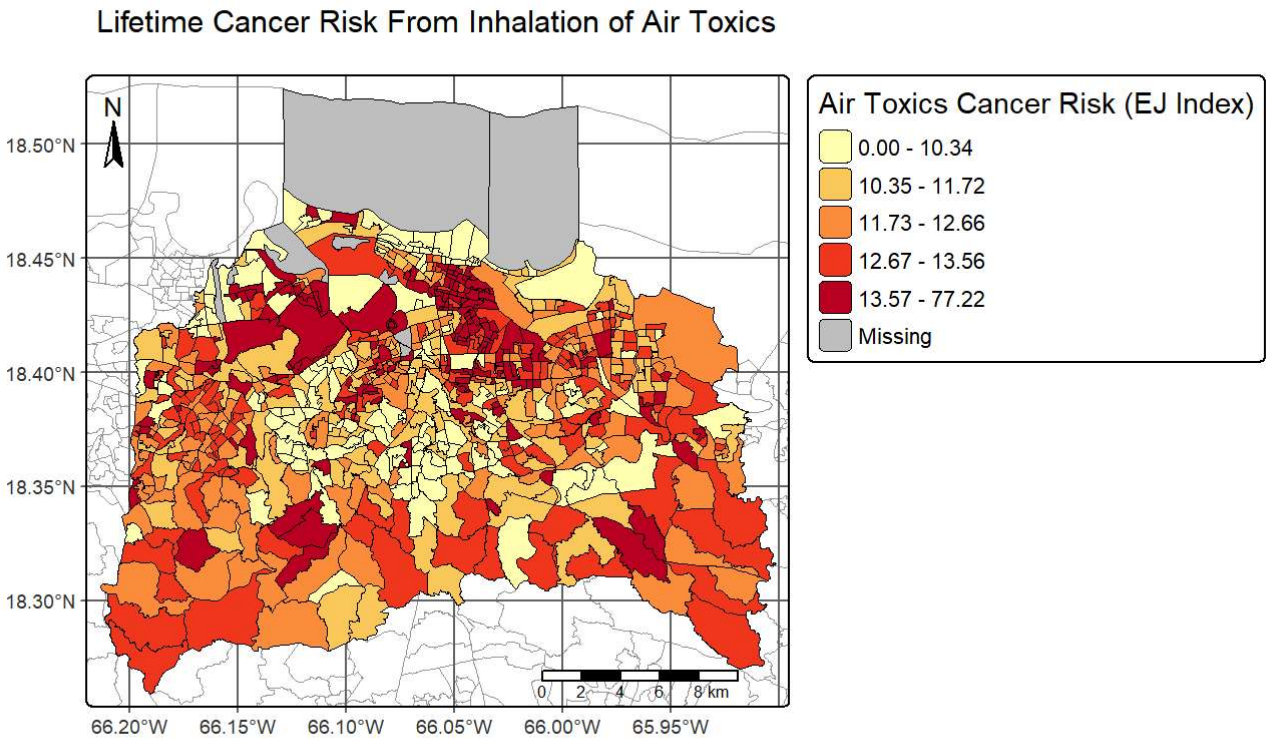
```r
# Show shape of the study area
tm_shape(metro) +

  #Show latitude and longitude lines
  tm_graticules(col = "gray40") +

  #Show low income percentile data
  tm_polygons("P_LOWINCPCT",
              lwd = 0.5,
              title = "Low Income Percentile (EJ Screen)",
              palette = "Purples",
              border.col = "black",
              style = "quantile") +

  #Add the title, specify legend location, and specify if the map will have a frame
  tm_layout(main.title = "Percentile of Low Income Block Groups in the Metropolitan Area of Puerto
            legend.outside = TRUE,
            frame = TRUE) +

  #Add a scale bar
  tm_scale_bar(position = c(0.6,0.1)) +

  #Add a compass
  tm_compass(type = "arrow", size = 1.5, position = c(0, 0.99))
```



Map 2: EJ Index of Cancer Risk to Toxic Air Pollutants

```
#Show outline of the island, but with the extent of the study area
tm_shape(puerto_rico, bbox = st_bbox(metro)) +

  #Show borders of puerto rico
  tm_borders(col = "gray60", lwd = 0.5) +

# Show shape of the study area
tm_shape(metro) +

  #Show latitude and longitude lines
  tm_graticules(col = "gray40") +

  #Show Cancer Risk to Air Toxics data
  tm_polygons("D2_CANCER",
              lwd = 0.5,
              title = "Air Toxics Cancer Risk (EJ Index)",
              palette = "brewer.yl_or_rd",
              border.col = "black",
              style = "quantile") +
```

```
#Add title, legend location and specify if the map will have a frame
tm_layout(main.title = "Lifetime Cancer Risk From Inhalation of Air Toxics",
          legend.outside = TRUE,
          frame = TRUE) +

#Add a scale bar
tm_scale_bar(position = c(0.63,0.079)) +

#Add a compass
tm_compass(type = "arrow", size = 1.5, position = c(0, 0.99))
```



Interpretation

This project explored environmental injustice across six municipalities in Puerto Rico by examining the relationship between low-income communities and cancer risk from air toxics. The first map displays the percentile of low-income populations (P_LOWINCPCT), while the second highlights block groups with higher Environmental Justice Index scores for cancer risk associated with air toxics (D2_CANCER). When compared, the maps indicate that areas with higher low-income percentiles often coincide with those facing elevated cancer risk. This finding suggests that economically disadvantaged communities may experience greater exposure to harmful air pollutants. Together, these maps underscore how socioeconomic vulnerability and environmental health risks intersect across the most densely populated region of the

island. Further analysis on this issue may examine whether communities of higher proportions of people of color also face greater cancer risk from toxic air pollutants. This could shed light on how ethnic background and income shapes environmental health injustice in this region.

Citation

U.S. Environmental Protection Agency. (2023). EJScreen: Environmental Justice Screening and Mapping Tool (Version 2.1) [Data set]. U.S. Environmental Protection Agency. https://www.epa.gov/ejscreen