Mapping Census Data in R

Workshop - Fall 2024

2024-08-15

Installing the packages

We are going to start by installing the following packages

```
install.packages(c("tidycensus", "tidyverse", "mapview", "ggspatial", "leafsync", "ggplot2"))
```

tidycensus: allows users to interface with a select number of the US Census Bureau's data APIs and return tidyverse-ready data frames, optionally with simple feature geometry included.

tidyverse: is a collection of open-source R packages that help with data science tasks like importing, tidying, manipulating, and visualizing data

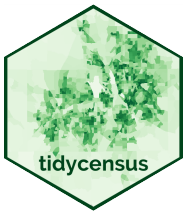
mapview: is a tool for quickly creating interactive maps of spatial data.

ggspatial: is a framework for interacting with spatial data using ggplot2 to create maps.

leafsync: is a plugin for leaflet to produce potentially synchronised small multiples of leaflet web maps wrapping Leaflet.

The tidycensus package

In this tutorial we will be using tidycensus package, developed by Kyle Walker.



tidycensus is an R package that allows users to interface with a select number of the US Census Bureau's data APIs and return tidyverse-ready data frames, optionally with simple feature geometry included.

Essential functions

`get_decennial()`, which requests data from the US Decennial Census APIs for 2000, 2010, and 2020.

`get_acs()`, which requests data from the 1-year and 5-year American Community Survey samples. Data are available from the 1-year ACS back to 2005 and the 5-year ACS back to 2005-2009.

`get_estimates()`, an interface to the Population Estimates APIs. These datasets include yearly estimates of population characteristics by state, county, and metropolitan area, along with components of change demographic estimates like births, deaths, and migration rates.

`get_pums()`, which accesses data from the ACS Public Use Microdata Sample APIs. These samples include anonymized individual-level records from the ACS organized by household and are highly useful for many different social science analyses. get_pums() is covered in more depth in Chapters 9 and 10.

`get_flows()`, an interface to the ACS Migration Flows APIs. Includes information on in- and out-flows from various geographies for the 5-year ACS samples, enabling origin-destination analyses.

Get ACS data

About the ACS

The American Community Survey ACS is a nationwide survey that collects and publishes information about the US population's social, economic, housing, and demographic characteristics.

The ACS provides data on topics such as: income, jobs and occupations, educational attainment, veterans, and housing tenure.

The ACS produces two types of estimates:

- 1-year estimates: Available for geographic areas with populations of 65,000 or more. These estimates are more current.
- 5-year estimates: Available for all geographic areas, including census tracts and block groups. These estimates are more statistically reliable, especially for smaller population groups

Getting a specific variable for all counties in one state.

We are going to start exploring census data at the county level. We are going to ask for a table with the total population for each county in the State of Pennsylvania.

1. Load the package with the following command

```
library(tidycensus)
```

```
Warning: package 'tidycensus' was built under R version 4.3.3
```

2. Create a new object named `latino_pop_PA` with the following code

Be aware that the property `geography =` is being specified with the string `"county"` to get data at this level. We are setting the property `state =` to retrieve all counties in Pennsylvania by defining the value `"PA"`. The line `variables =` comtains the identificator for the total of population in the original census table. We will see how to identify the variables ID in the following steps.

```
latino_pop_PA <- get_acs(
  geography = "county",
  state = "PA",
  variables = "B03001_003",
  year = 2022
)
```

```
Getting data from the 2018-2022 5-year ACS
```

```
latino_pop_PA
```

```
# A tibble: 67 x 5
   GEOID NAME                           variable   estimate   moe
   <chr> <chr>                          <chr>         <dbl> <dbl>
 1 42001 Adams County, Pennsylvania     B03001_003     7688    NA
 2 42003 Allegheny County, Pennsylvania B03001_003    29272    NA
 3 42005 Armstrong County, Pennsylvania B03001_003      560    NA
 4 42007 Beaver County, Pennsylvania    B03001_003     3227    NA
 5 42009 Bedford County, Pennsylvania   B03001_003      598    NA
 6 42011 Berks County, Pennsylvania     B03001_003    99460    NA
 7 42013 Blair County, Pennsylvania     B03001_003     1721    NA
 8 42015 Bradford County, Pennsylvania  B03001_003      946    NA
```

```
 9 42017 Bucks County, Pennsylvania     B03001_003    38195    NA
10 42019 Butler County, Pennsylvania    B03001_003     3391    NA
# i 57 more rows
```

The column `estimate` shows the number of latino population for each county in Pennsylvania, while the column `moe` shows the margin of error around it.

Exploring the original census file variables

As mentioned, each variable has its unique identifier in the original file. You will need to know the identifier of the variables you want to get in order to process a file in your project. To explore the variables in the original files you can use the `load_variables()` function specifying the year and dataset.

For example you can use the following to get the ACS 2022 5-year-estimate variables.

```
vars <- load_variables(2022, "acs5")

head(vars)
```

```
# A tibble: 6 x 4
  name        label                                      concept          geography
  <chr>       <chr>                                      <chr>            <chr>
1 B01001A_001 Estimate!!Total:                           Sex by Age (Whi~ tract
2 B01001A_002 Estimate!!Total:!!Male:                    Sex by Age (Whi~ tract
3 B01001A_003 Estimate!!Total:!!Male:!!Under 5 years     Sex by Age (Whi~ tract
4 B01001A_004 Estimate!!Total:!!Male:!!5 to 9 years      Sex by Age (Whi~ tract
5 B01001A_005 Estimate!!Total:!!Male:!!10 to 14 years    Sex by Age (Whi~ tract
6 B01001A_006 Estimate!!Total:!!Male:!!15 to 17 years    Sex by Age (Whi~ tract
```

The resulting table will have a column `name` with the variable code (you will input this text in the `get_acs()` function), a `label` column with the description fo the variable, a `concept` with the group variable and a `geography` column specifying the smallest level at which the variable is available.

For our purpose, the ACS 2022 variables that contain the number of people of Hispanic or Latino Origin are from row 580 to 609. Here is an extract of these rows.

```
vars[580:609,]
```

```
# A tibble: 30 x 4
   name       label                                               concept geography
   <chr>      <chr>                                               <chr>   <chr>
 1 B03001_002 Estimate!!Total:!!Not Hispanic or Latino            Hispan~ tract
 2 B03001_003 Estimate!!Total:!!Hispanic or Latino:               Hispan~ tract
 3 B03001_004 Estimate!!Total:!!Hispanic or Latino:!!Mexican      Hispan~ tract
 4 B03001_005 Estimate!!Total:!!Hispanic or Latino:!!Puerto R~    Hispan~ tract
 5 B03001_006 Estimate!!Total:!!Hispanic or Latino:!!Cuban        Hispan~ tract
 6 B03001_007 Estimate!!Total:!!Hispanic or Latino:!!Dominica~    Hispan~ tract
 7 B03001_008 Estimate!!Total:!!Hispanic or Latino:!!Central ~    Hispan~ tract
 8 B03001_009 Estimate!!Total:!!Hispanic or Latino:!!Central ~    Hispan~ tract
 9 B03001_010 Estimate!!Total:!!Hispanic or Latino:!!Central ~    Hispan~ tract
10 B03001_011 Estimate!!Total:!!Hispanic or Latino:!!Central ~    Hispan~ tract
# i 20 more rows
```

Getting tables from the ACS

Another way to get variables from the ACS is to use the `table =` property in tidycensus. Instead of returning one single variable as we did in the previous step, this will return a table with all variables in the `B03001` set that contains all latino population `B03001_003`, along with:

Table 1: B03001 Table

Code	Variable
B03001_004	Mexican
B03001_005	Puerto Rican
B03001_006	Cuban
B03001_007	Dominican
B03001_009	Costa Rican
B03001_010	Guatemalan
B03001_011	Honduran
B03001_012	Nicaraguan
B03001_013	Panamanian
B03001_014	Salvadoran
B03001_015	Other Central American
B03001_017	Argentinian
B03001_018	Bolivian
B03001_019	Chilean
B03001_020	Colombian
B03001_021	Ecuadorian
B03001_022	Paraguayan

Code	Variable
B03001_023	Peruvian
B03001_024	Uruguayan
B03001_025	Venezuelan
B03001_026	Other South American
B03001_027	Other Hispanic or Latino

```
latino_table_PA <- get_acs(
  geography = "county",
  state = "PA",
  ##county = "Philadelphia",
  table = "B03001",
  year = 2022,
  output = "wide"
)
```

```
Getting data from the 2018-2022 5-year ACS
```

```
Loading ACS5 variables for 2022 from table B03001. To cache this dataset for faster access t
```

```
latino_table_PA
```

```
# A tibble: 67 x 64
   GEOID NAME        B03001_001E B03001_001M B03001_002E B03001_002M B03001_003E
   <chr> <chr>             <dbl>       <dbl>       <dbl>       <dbl>       <dbl>
 1 42001 Adams Coun~      104604          NA       96916          NA        7688
 2 42003 Allegheny ~     1245310          NA     1216038          NA       29272
 3 42005 Armstrong ~       65538          NA       64978          NA         560
 4 42007 Beaver Cou~      167629          NA      164402          NA        3227
 5 42009 Bedford Co~       47613          NA       47015          NA         598
 6 42011 Berks Coun~      428483          NA      329023          NA       99460
 7 42013 Blair Coun~      122640          NA      120919          NA        1721
 8 42015 Bradford C~       60159          NA       59213          NA         946
 9 42017 Bucks Coun~      645163          NA      606968          NA       38195
10 42019 Butler Cou~      194562          NA      191171          NA        3391
# i 57 more rows
# i 57 more variables: B03001_003M <dbl>, B03001_004E <dbl>, B03001_004M <dbl>,
#   B03001_005E <dbl>, B03001_005M <dbl>, B03001_006E <dbl>, B03001_006M <dbl>,
#   B03001_007E <dbl>, B03001_007M <dbl>, B03001_008E <dbl>, B03001_008M <dbl>,
#   B03001_009E <dbl>, B03001_009M <dbl>, B03001_010E <dbl>, B03001_010M <dbl>,
```

```
#   B03001_011E <dbl>, B03001_011M <dbl>, B03001_012E <dbl>, B03001_012M <dbl>,
#   B03001_013E <dbl>, B03001_013M <dbl>, B03001_014E <dbl>, ...
```

Note that this table contains both the `estimate` for the variable end the `error`. All variable names ending with `E` contain the estimate.

Exploring the percentage of latino population by county

To explore the percentage of latino population we arw going to create a graph with bars showing this variable. First, we clean up the county names to contain the name of the county only.

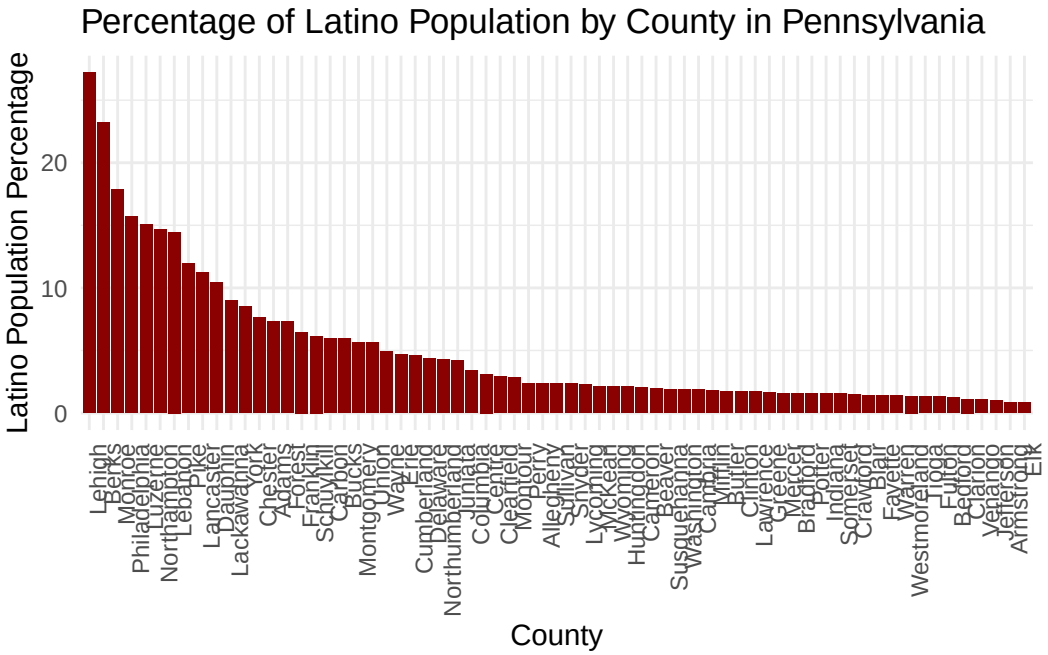
```
latino_table_PA$NAME <- gsub(" County|, Pennsylvania", "", latino_table_PA$NAME)
```

Second, we calculate the percentage of latino population by dividing the number of latinos by the total population on each county. We add this new variable `latino_percentage` to our table.

```
latino_table_PA$latino_percentage <- (latino_table_PA$B03001_003E / latino_table_PA$B03001_0
```

Lastly, we plot the percentage in bars using the `ggplot()` and `geom_bar()` options.

```
library("ggplot2")
ggplot(latino_table_PA, aes(x = reorder(NAME, -latino_percentage), y = latino_percentage)) +
  geom_bar(stat = "identity", fill = "darkred") +
  labs(
    x = "County",
    y = "Latino Population Percentage",
    title = "Percentage of Latino Population by County in Pennsylvania"
  ) +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 90, hjust = 1))
```



As seen in the graph, Lehigh County has the highest percentage of latino population (more than 35%) followed by Berks and Monroe (more than 20%) and Philadelphia, Luzerne, Northhampton, Lebanon, Pike, Lancaster and Dauphin (more than 10%).

Creating a map with the ACS data

In this section we are going to answer the question:

> **Guiding question**
>
> What is the spatial distribution of the percentage of latino population in the State of Pennsylvania?

To do so, we are going to explore additional properties on the `get_acs()` function and how to use it to generate different types of maps.

Getting the geometry from the census

To build a map with the census and ACS data we will need the geometry (polygons) of the geography we are adding the data to. In this exmaple, the counties.

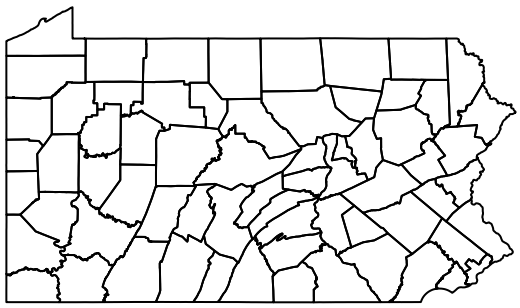
The `geometry = TRUE` option of the tidycensus package has the ability to download an additional column that stores a polygon geometry of the corresponding geographic level, in this case the counties.

If you rerun the code below, adding the `geometry = TRUE` option, the resulting table will have an additional column.

```
latino_table_PA <- get_acs(
  geography = "county",
  state = "PA",
  table = "B03001",
  year = 2022,
  output = "wide",
  geometry = TRUE
)
```

We can plot the polygons with the following line.

```
plot(latino_table_PA$geometry)
```



Creating a choroplet map from an ACS variable

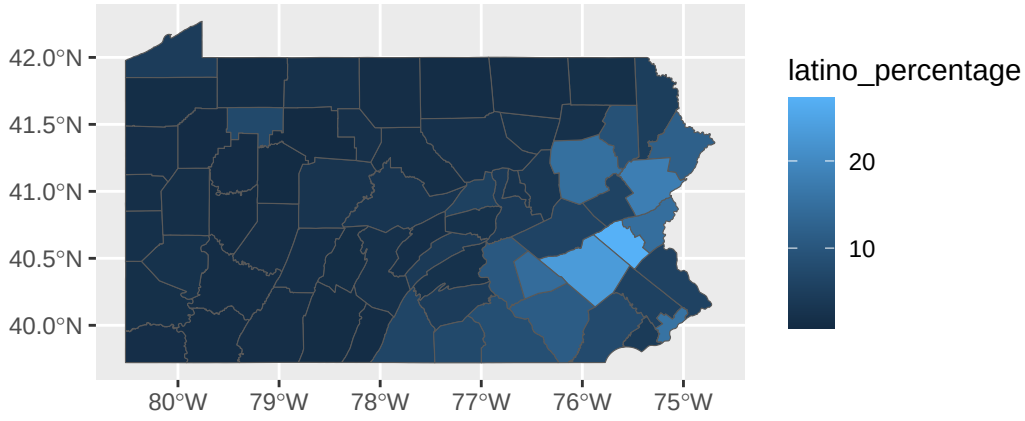
To answer our guiding question we are going to plot the percentage of latino population in a map.

First, we are going to calculate the percentage of latino population on the table that contains geometry.

```
latino_table_PA$latino_percentage <- (latino_table_PA$B03001_003E / latino_table_PA$B03001_0
```

Now, we can simply use the same `ggpllot` code line we used before to get a map of this variable. We set the data property to point to our `latino_table_PA` table and the fill option to the variable that contains the percentage we created in the previous step. The `geom_sf()` function is used to read the `geomtry` field as polygons and render them in a map.

```
ggplot(data = latino_table_PA, aes(fill = latino_percentage)) +
  geom_sf()
```

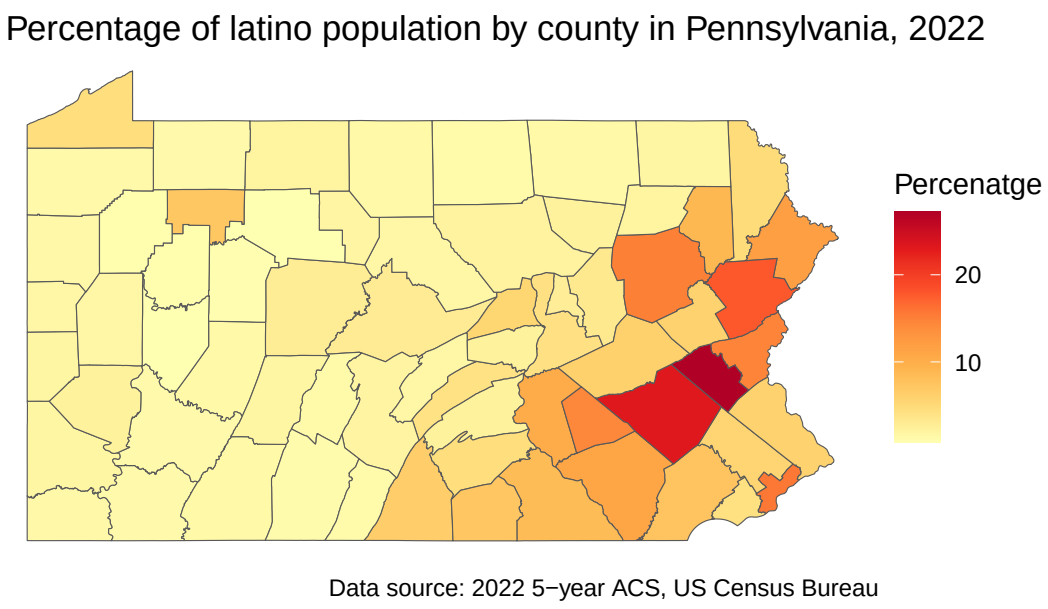


Customizing the choroplet map

For a customized version of the map, we can use the `scale_fill_distiller()` function that allows choosing from different map color palettes and `labs()` function to specify the general title, footnote caption and key title of the map.

If you want to know more about the color ramps go to ColorBrewer.

```
ggplot(data = latino_table_PA, aes(fill = latino_percentage)) +
  geom_sf() +
  scale_fill_distiller(palette = "YlOrRd",
                       direction = 1) +
  labs(title = "  Percentage of latino population by county in Pennsylvania, 2022",
       caption = "Data source: 2022 5-year ACS, US Census Bureau",
       fill = "Percenatge") +
  theme_void()
```



Exercise 1: Exploring other geometries, census tracts.

Although the counties map show certain spatial pattern, we know that not all the county is the same internally. If we explore this variable with more granularity, we might see different patterns.

Lets re-do the whole process but this time getting the data at the census tract level.

- Start by creating a table `latino_table_tracts_PA` and setting the `geography =` to "tract". All the rest can remain the same.

> **Attention**
>
> This process might take longer than the ones we run before due to a higher number of records.

```
latino_table_tracts_PA <- get_acs(
  geography = "tract",
  state = "PA",
  table = "B03001",
  year = 2022,
  output = "wide",
  geometry = TRUE
)
```

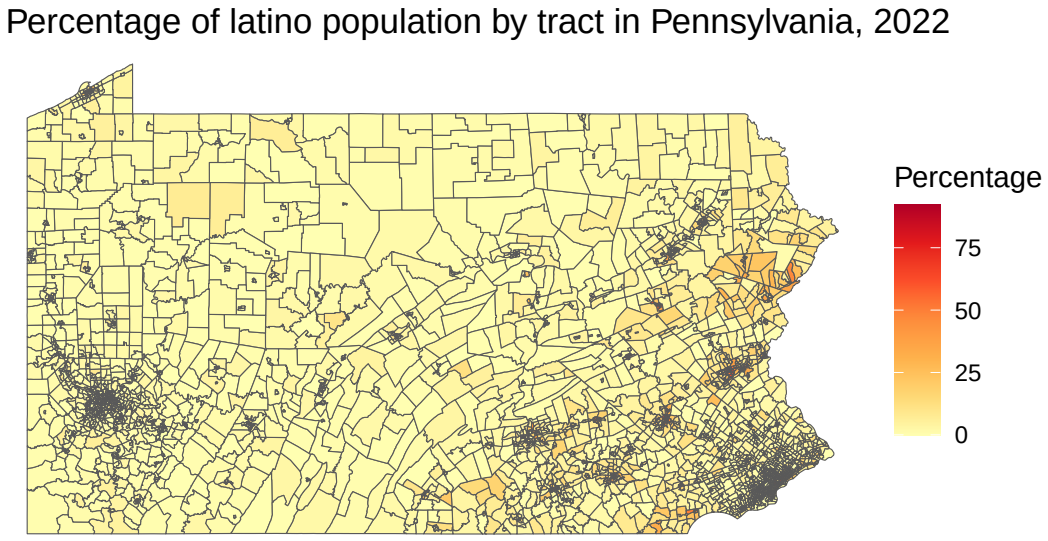
- Now, lets calculate the percentage of latino population on each tract.

```
latino_table_tracts_PA$latino_percentage <- ifelse(latino_table_tracts_PA$B03001_003E>0, 100
```

In this case we used an `ifelse` clause because some tracts have 0 latino population and we want to avoid having null values in our results.

- And lastly, lets create the map using the table and variable we just created.

```
ggplot(data = latino_table_tracts_PA, aes(fill = latino_percentage)) +
  geom_sf() +
  scale_fill_distiller(palette = "YlOrRd",
                       direction = 1) +
  labs(title = "  Percentage of latino population by tract in Pennsylvania, 2022",
       caption = "Data source: 2022 5-year ACS, US Census Bureau",
       fill = "Percentage") +
  theme_void()
```

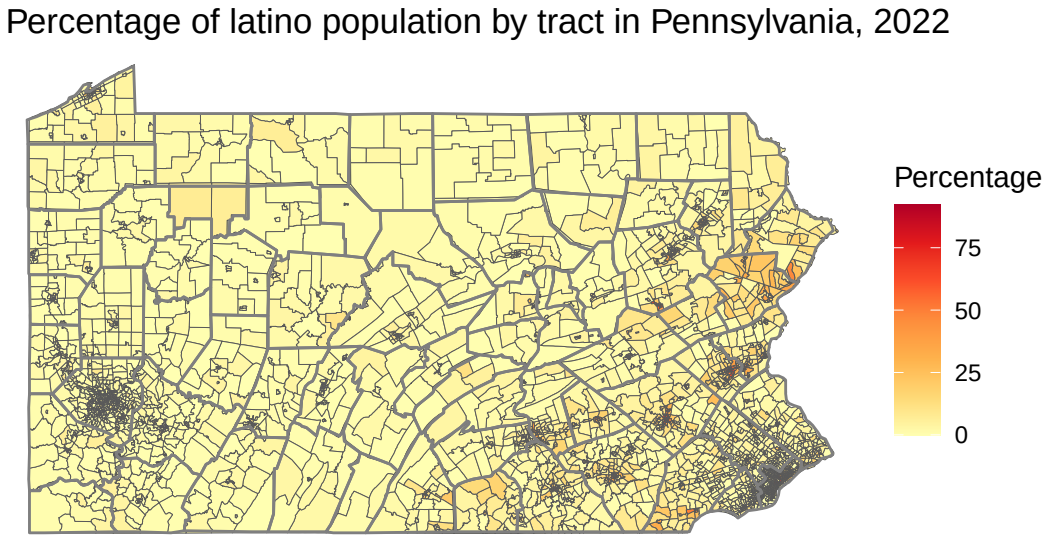


Where did the people go?

In this case, it is convenient to change the polygon outline thickness by adding `linewidth = 0.01` to the `geom_sf()` function.

We can also add the county outlines to identify them by addind `borders("county","pennsylvania")`.

```
## install.packages("maps")
library("maps")

ggplot(data = latino_table_tracts_PA, aes(fill = latino_percentage)) +
  geom_sf(linewidth=0.01) +
  scale_fill_distiller(palette = "YlOrRd",
                       direction = 1) +
  labs(title = "  Percentage of latino population by tract in Pennsylvania, 2022",
       caption = "Data source: 2022 5-year ACS, US Census Bureau",
       fill = "Percentage") +
  borders("county","pennsylvania") +
  theme_void()
```



Exercise 2: Focusing on a specific county: Lehigh County.

We are going to focus on the county with the highest percentage of Latino population, Lehigh County.

For that, lets start generating a specific table for that county.

Notice that we set the table name to `lehigh_latino`, the `geography = tract` and added `county = "Lehigh"` to get all tracts in Lehigh County.

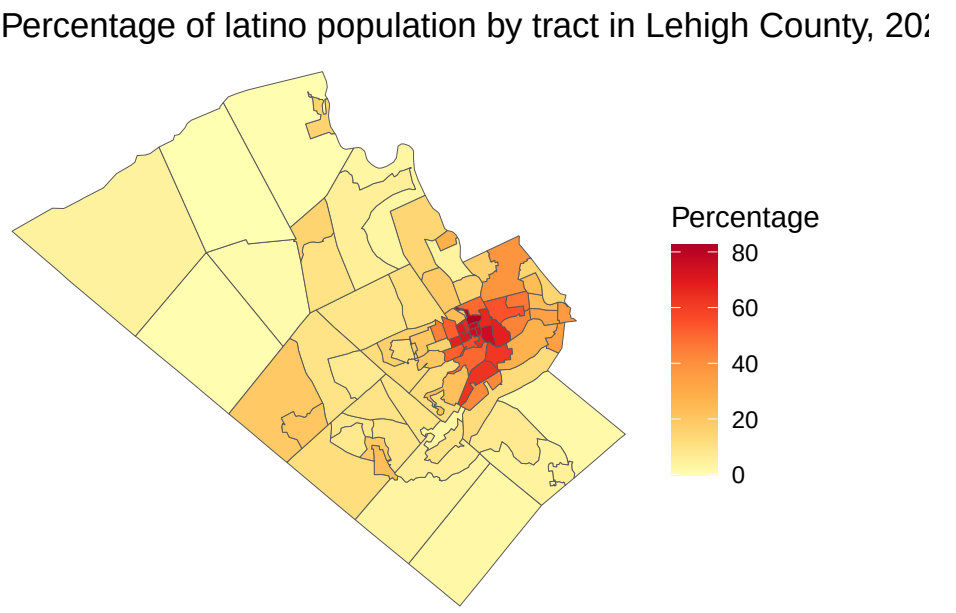
```
lehigh_latino <- get_acs(
  geography = "tract",
  state = "PA",
  county = "Lehigh",
  table = "B03001",
  year = 2022,
  output = "wide",
  geometry = TRUE
)
```

Now lest calculate the percentage of latinos using the same code we used before. Be sure to use the correct table name `lehigh_latino`.

```
lehigh_latino$latino_percentage <- ifelse(lehigh_latino$B03001_003E>0, 100* (lehigh_latino$B
```

And now, lets generate a choroplet map as the last we did.

```
ggplot(data = lehigh_latino, aes(fill = latino_percentage)) +
  geom_sf(linewidth=0.01) +
  scale_fill_distiller(palette = "YlOrRd",
                       direction = 1) +
  labs(title = "  Percentage of latino population by tract in Lehigh County, 2022",
       caption = "Data source: 2022 5-year ACS, US Census Bureau",
       fill = "Percentage") +
  theme_void()
```



Again, in this map we can see that the highest percentage of latino population is located towards the center of the county while the outter tracts have very low values.

Customized interactive maps with mapgl()

There are multiple ways you can customize your maps in R. We are going to explore the `mapgl()` package to create interactive maps.

The mapgl() package

The mapgl R package allows users to create interactive maps in R using the Mapbox GL JS and MapLibre GL JS libraries:

Features Create globe visualizations, layer objects to make filled maps, circle maps, heatmaps, and 3D graphics, and customize map styles and views.

Ease of use Designed to be intuitive for R users while still offering the capabilities of the Mapbox GL JS and MapLibre GL JS libraries

Flexibility Allows for more code to be written when making maps, but also gives users more flexibility in how they design their maps

Shiny web applications Includes utilities to use Mapbox and MapLibre maps in Shiny web applications

Find more information on the mapgl package.

Getting started with mapgl

The mapgl package lets you create maps using Mapbox and Maplibre. These two are javascript libraries that render interactive maps in the web. For this demo, we are using Maplibre since it is open-source and free to use.

Lets start by installing the mapgl package and calling the library with the code below.

```
install.packages("mapgl")
```

```
library(mapgl)
```

To initialize a map we will need the following line of code.

```
maplibre()
```

```
file:////private/tmp/Rtmpo9xoKH/file446531507f24/widget44651bcb2dc7.html screenshot completed
```

MapLibre | © CARTO, © OpenStreetMap contributors

It will display a map of the world with the default basemap from CARTO's Voyager tiles.

You can set some things in the map by using `style =`, `center =`, `zoom =`, `bearing =`, `pitch =`, and others. We are going to initialize a map centered at Temple University Charles Library in Philadelphia, PA. To do so, I added `center = c(-75.15541, 39.98215)` the geographic coordinates of the building and `zoom = 16` a zoom that is closer to this part of the city.

```
maplibre(
  center = c(-75.15541, 39.98215),
  zoom = 16,
)
```

```
file:////private/tmp/Rtmpo9xoKH/file44653704bd01/widget44651814a8df.html screenshot complete
```

MapLibre | © CARTO, © OpenStreetMap contributors

Adding census data to maplibre

Now, we are going to initialize a map centered in the State of Pennsylvania using the table we created before `latino_table_PA`. We are going to store this map in the variable `pa_map`.

```
pa_map <- maplibre(bounds = latino_table_PA)

pa_map
```

```
file:////private/tmp/Rtmpo9xoKH/file44656204949b/widget44651ab87e63.html screenshot complete
```

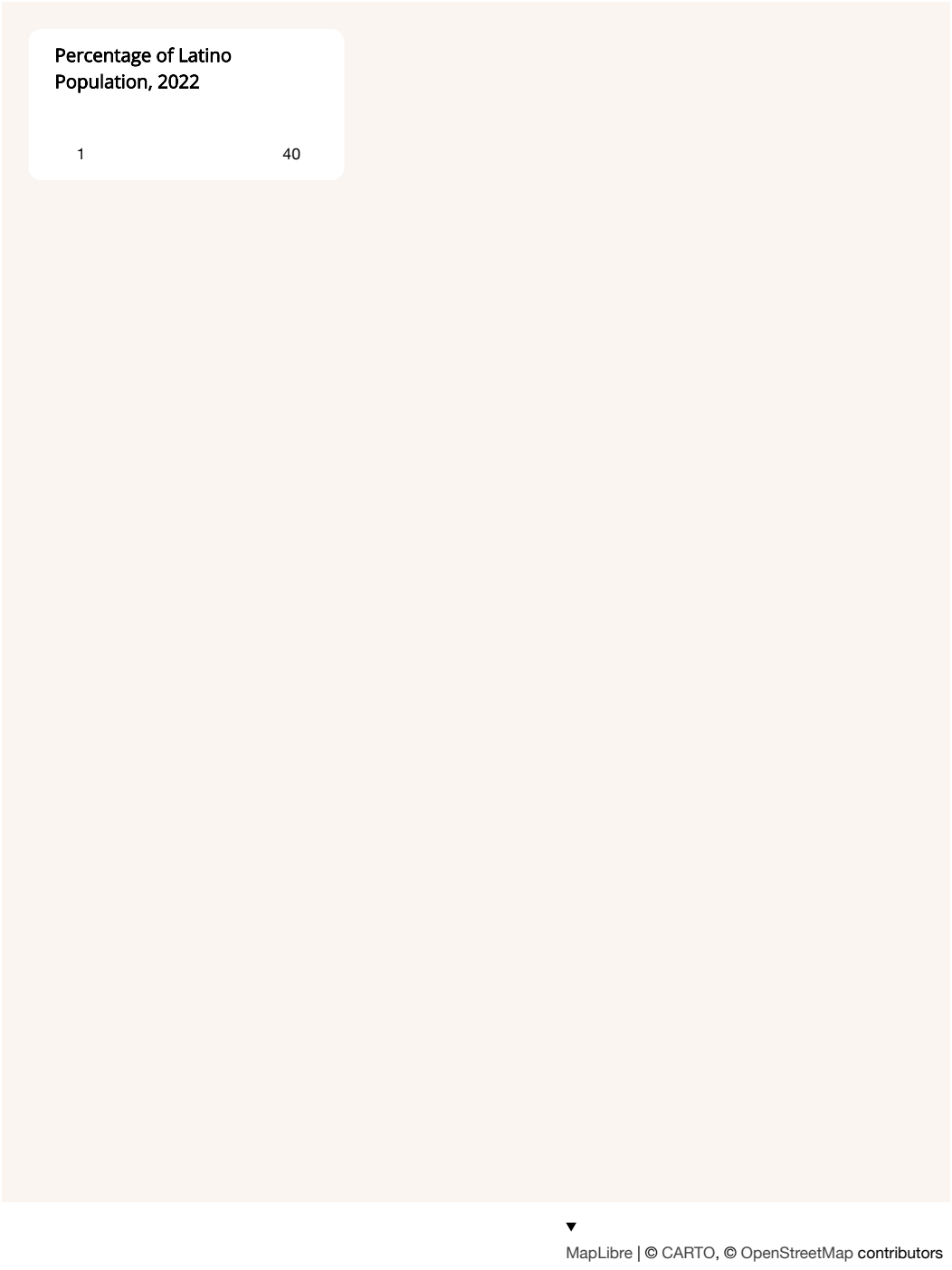
MapLibre | © CARTO, © OpenStreetMap contributors

In the following code, we are going to add a layer and a legend to our map. With the `add_fill_layer()` we are able to call the `column = "latino_percentage` from our `source = latino_table_PA`. We are setting a continuous color ramp using values between 1 and 40 to accomodate the colors between light yellow and dark orange.To improve the visualization of the reference data in the background we set `fill_oppacity = 0.7`.

To add a legend we simply used the same settings for `values` and `colors` that we used previously and added a title.

```
pa_map |>
  add_fill_layer(
  id = "pa_latino",
  source = latino_table_PA,
  fill_color = interpolate(
    column = "latino_percentage",
    values = c(1, 40),
    stops = c("lightyellow", "darkorange"),
    na_color = "lightgrey"
  ),
  fill_opacity = 0.7
 ) |>
  add_legend(
    "Percentage of Latino Population, 2022",
    values = c(1, 40),
    colors = c("lightyellow", "darkorange")
  )
```

```
file:////private/tmp/Rtmpo9xoKH/file44655e71c4ef/widget44657f385759.html screenshot complete
```


Percentage of Latino Population, 2022
1
40
MapLibre | © CARTO, © OpenStreetMap contributors

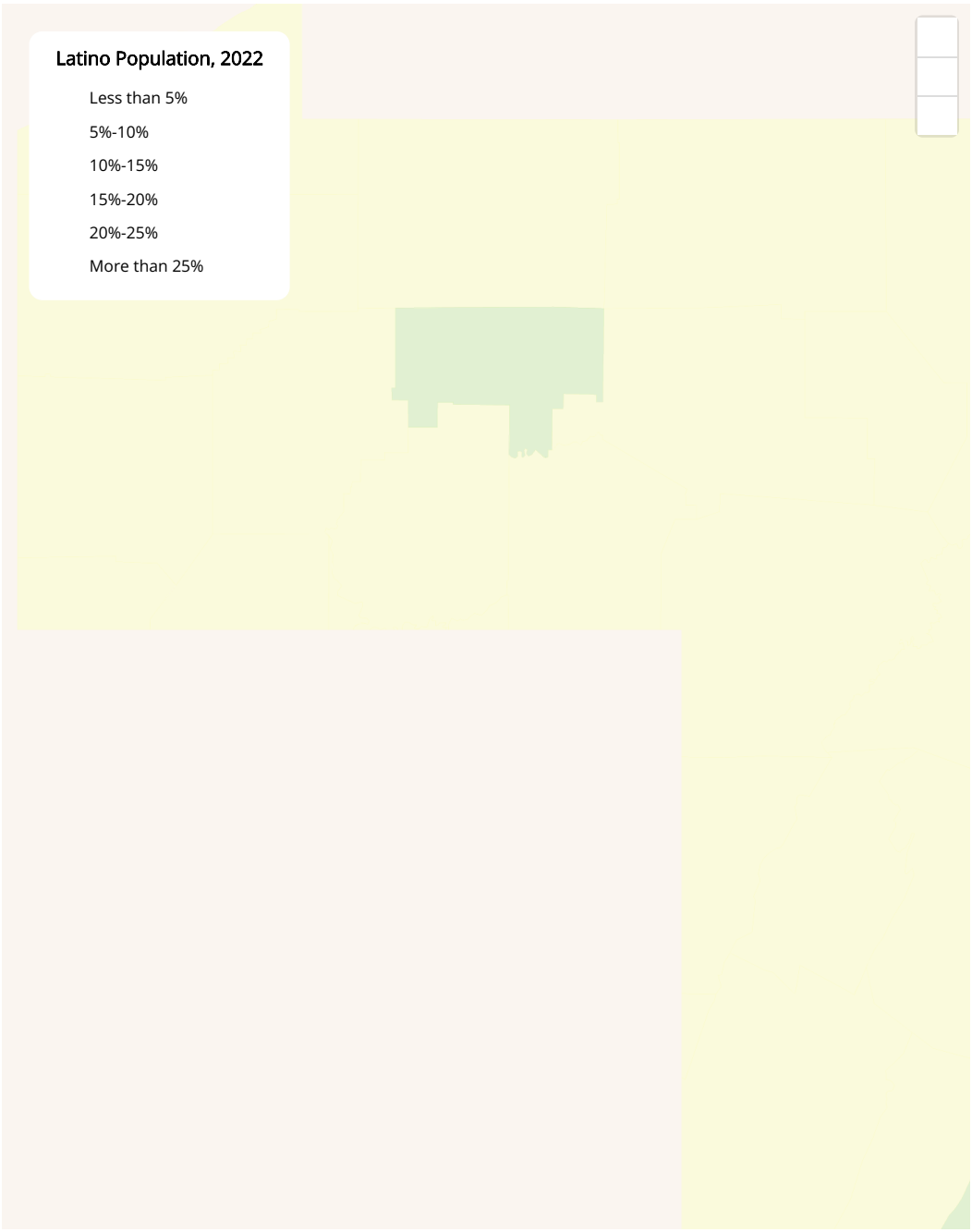
Adding interactivity to your map

There are several ways you can make you map interactive. From adding navigation controls using `add_navigation_control()` to adding a `popup` and `tooltip`. In the following code, we also use a categorical styling instead of a continous color ramp.

```
latino_table_PA$popup <- glue::glue(
  "<strong>County: </strong>{latino_table_PA$NAME}<br><strong>Percentage: </strong>{sprintf(
)



brewer_pal <- RColorBrewer::brewer.pal(6, "YlGnBu")

pa_map |>
  add_fill_layer(
    id = "pa_latino",
    source = latino_table_PA,
    fill_color = step_expr(
      column = "latino_percentage",
      base = brewer_pal[1],
      stops = brewer_pal[1:6],
      values = seq(0.8, 27.2, length.out = 6),
      na_color = "white"
    ),
    fill_opacity = 0.5,
    popup = "popup",
    tooltip = "latino_percentage",
    hover_options = list(
      fill_color = "yellow",
      fill_opacity = 1
    )
  ) |>
  add_legend(
    "Latino Population, 2022",
    values = c(
      "Less than 5%",
      "5%-10%",
      "10%-15%",
      "15%-20%",
      "20%-25%",
      "More than 25%"
    ),
    colors = brewer_pal,
```

```
    type = "categorical"
  ) |>
  add_navigation_control()
```

```
file:////private/tmp/Rtmpo9xoKH/file4465299cf9f1/widget4465dd528f.html screenshot completed
```


Latino Population, 2022
Less than 5%
5%-10%
10%-15%
15%-20%
20%-25%
More than 25%
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Exercise 3: Redo the interactive map for Philadelphia County

Now we are going to redo the interactive map for a specific county. We can use the same code we used in step 5.5 to create a new table for Philadelphia. We also calculated the percentage of latino population.

```
philly_latino <- get_acs(
  geography = "tract",
  state = "PA",
  county = "Philadelphia",
  table = "B03001",
  year = 2022,
  output = "wide",
  geometry = TRUE
)

philly_latino$latino_percentage <- ifelse(
  philly_latino$B03001_003E > 0,
  round(100 * (philly_latino$B03001_003E / philly_latino$B03001_001E), 2),
  0
)
```

We initialize the map with the following code.

```
philly_map <- maplibre(bounds = philly_latino)
```

Now, lets build the interactive map.

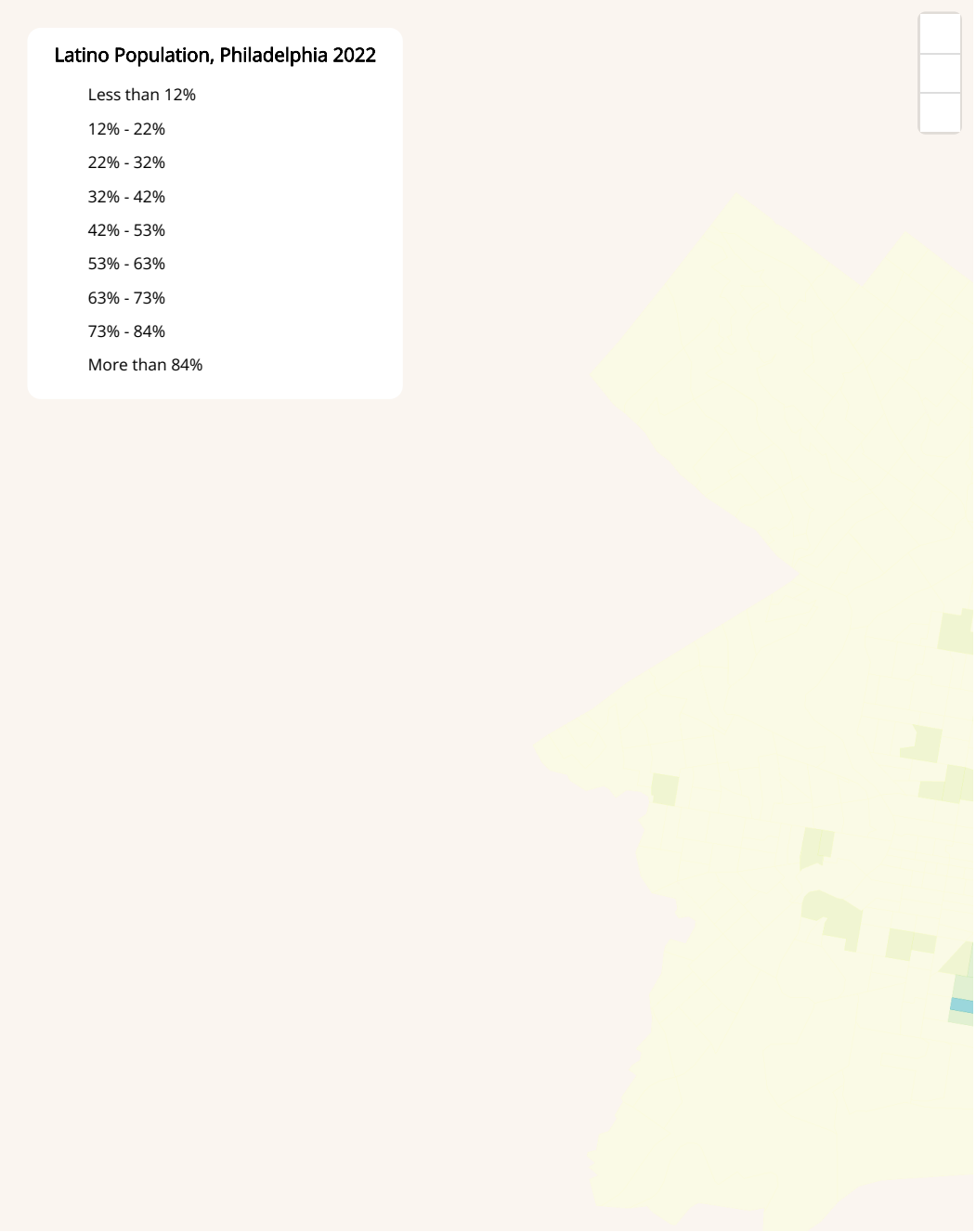
```
philly_latino$popup <- glue::glue(
  "<strong>Name: </strong>{philly_latino$GEOID}<br><strong>Percentage: </strong>{philly_latin
)


brewer_pal <- RColorBrewer::brewer.pal(9, "YlGnBu")

philly_map |>
  add_fill_layer(
    id = "philly_latino",
    source = philly_latino,
    fill_color = step_expr(
      column = "latino_percentage",
      base = brewer_pal[1],
```

```
      stops = brewer_pal[1:9],
      values = seq(1, 92.03, length.out = 9),
      na_color = "white"
    ),
    fill_opacity = 0.5,
    popup = "popup",
    tooltip = "latino_percentage",
    hover_options = list(
      fill_color = "yellow",
      fill_opacity = 1
    )
  ) |>
  add_legend(
    "Latino Population, Philadelphia 2022",
    values = c(
      "Less than 12%",
      "12% - 22%",
      "22% - 32%",
      "32% - 42%",
      "42% - 53%",
      "53% - 63%",
      "63% - 73%",
      "73% - 84%",
      "More than 84%"
    ),
    colors = brewer_pal,
    type = "categorical"
  ) |>
  add_navigation_control()
```

```
file:////private/tmp/Rtmpo9xoKH/file44658003061/widget446544683461.html screenshot completed
```


Latino Population, Philadelphia 2022
Less than 12%
12% - 22%
22% - 32%
32% - 42%
42% - 53%
53% - 63%
63% - 73%
73% - 84%
More than 84%
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Workshop slides

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