Spatial data & visualization

Prof. Maria Tackett


STA 199

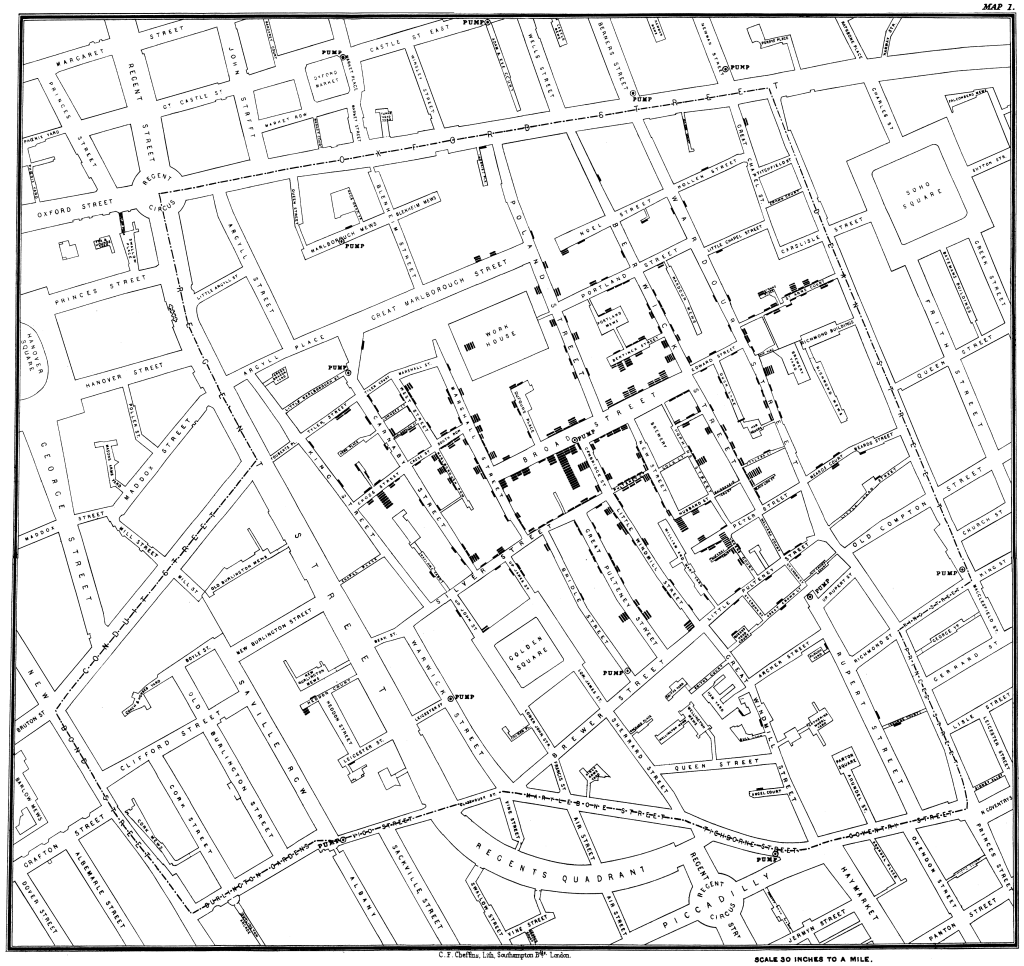
Click for PDF of slides

Introduction

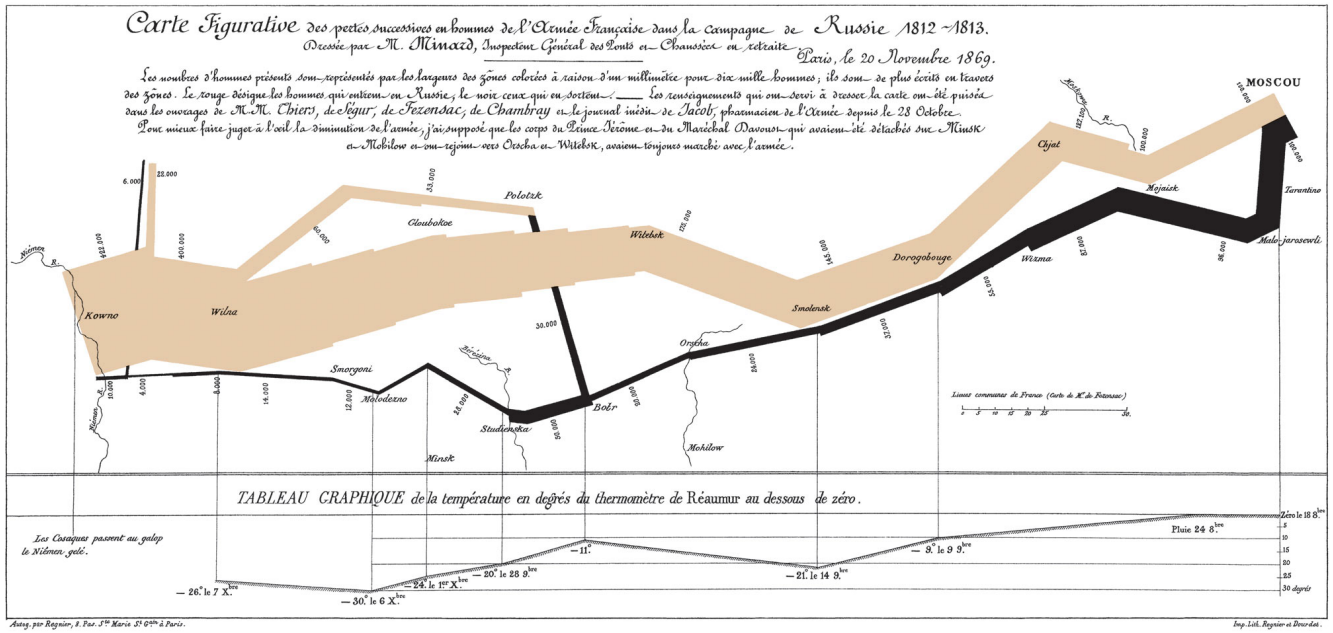
Spatial data is important

- exploratory data analysis
- detecting spatial patterns and trends
- understanding spatial data relationships
- analysis of spatial data should reflect spatial structure

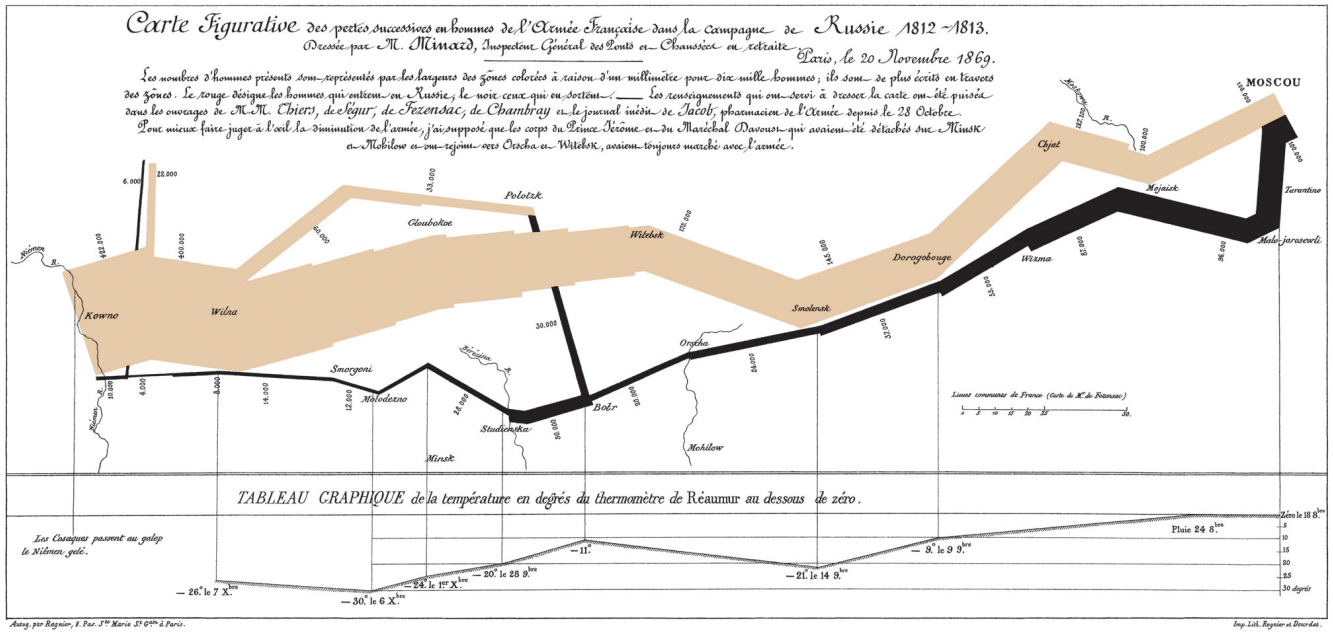
1854 London Cholera Outbreak



Napoleon's 1812 Russia Campaign



Napoleon's 1812 Russia Campaign



Many others!

- Migrations
- World Population Density
- Global Power

Spatial data is different

Our typical tidy data frame:

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
##  1  2013     1     1      517            515         2      830            819
##  2  2013     1     1      533            529         4      850            830
##  3  2013     1     1      542            540         2      923            850
##  4  2013     1     1      544            545        -1     1004           1022
##  5  2013     1     1      554            600        -6      812            837
##  6  2013     1     1      554            558        -4      740            728
##  7  2013     1     1      555            600        -5      913            854
##  8  2013     1     1      557            600        -3      709            723
##  9  2013     1     1      557            600        -3      838            846
## 10  2013     1     1      558            600        -2      753            745
## # … with 336,766 more rows, and 11 more variables: arr_delay <dbl>,
## #   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
## #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>, time_hour <dttm>
```

Spatial data is different

Our (new) simple feature object:

```
## Simple feature collection with 100 features and 3 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## geographic CRS: NAD27
## First 10 features:
##            name regstrd voted                       geometry
## 1          ASHE   19414  8428 MULTIPOLYGON (((-81.47276 3...
## 2     ALLEGHANY    7556  4101 MULTIPOLYGON (((-81.23989 3...
## 3         SURRY   46666 23660 MULTIPOLYGON (((-80.45634 3...
## 4     CURRITUCK   21803  7536 MULTIPOLYGON (((-76.00897 3...
## 5  NORTHAMPTON   13891  6196 MULTIPOLYGON (((-77.21767 3...
## 6      HERTFORD   14945  6955 MULTIPOLYGON (((-76.74506 3...
## 7        CAMDEN    8128  3472 MULTIPOLYGON (((-76.00897 3...
## 8         GATES    8294  3105 MULTIPOLYGON (((-76.56251 3...
## 9        WARREN   13441  6878 MULTIPOLYGON (((-78.30876 3...
## 10       STOKES   31649 14444 MULTIPOLYGON (((-80.02567 3...
```

Spatial data is different

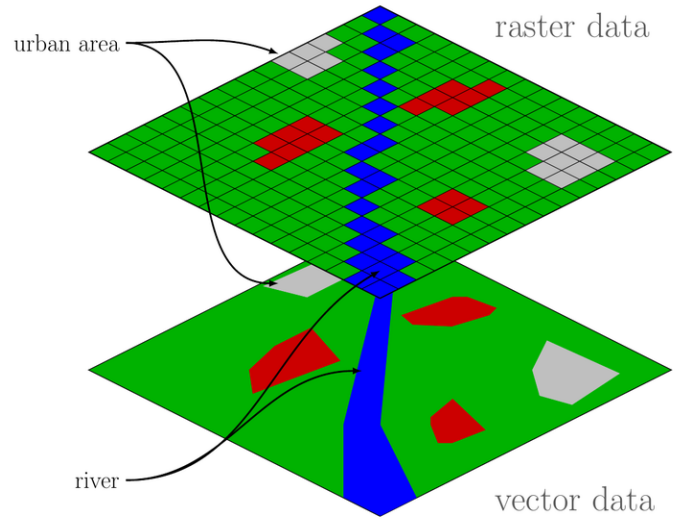
Our (new) simple feature object:

```
## Simple feature collection with 100 features and 3 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## geographic CRS: NAD27
## First 10 features:
##            name regstrd voted                       geometry
## 1          ASHE   19414  8428 MULTIPOLYGON (((-81.47276 3...
## 2     ALLEGHANY    7556  4101 MULTIPOLYGON (((-81.23989 3...
## 3         SURRY   46666 23660 MULTIPOLYGON (((-80.45634 3...
## 4     CURRITUCK   21803  7536 MULTIPOLYGON (((-76.00897 3...
## 5  NORTHAMPTON   13891  6196 MULTIPOLYGON (((-77.21767 3...
## 6      HERTFORD   14945  6955 MULTIPOLYGON (((-76.74506 3...
## 7        CAMDEN    8128  3472 MULTIPOLYGON (((-76.00897 3...
## 8         GATES    8294  3105 MULTIPOLYGON (((-76.56251 3...
## 9        WARREN   13441  6878 MULTIPOLYGON (((-78.30876 3...
## 10       STOKES   31649 14444 MULTIPOLYGON (((-80.02567 3...
```

Raster versus vector spatial data

Vector spatial data describes the world using shapes (points, lines, polygons, etc).

Raster spatial data describes the world using cells of constant size.



The choice to use vector or raster data depends on the problem context. We will focus on **vector** data.

Simple features

A **simple feature** is a standard way to describe how real-world spatial objects (country, building, tree, road, etc) can be represented by a computer.

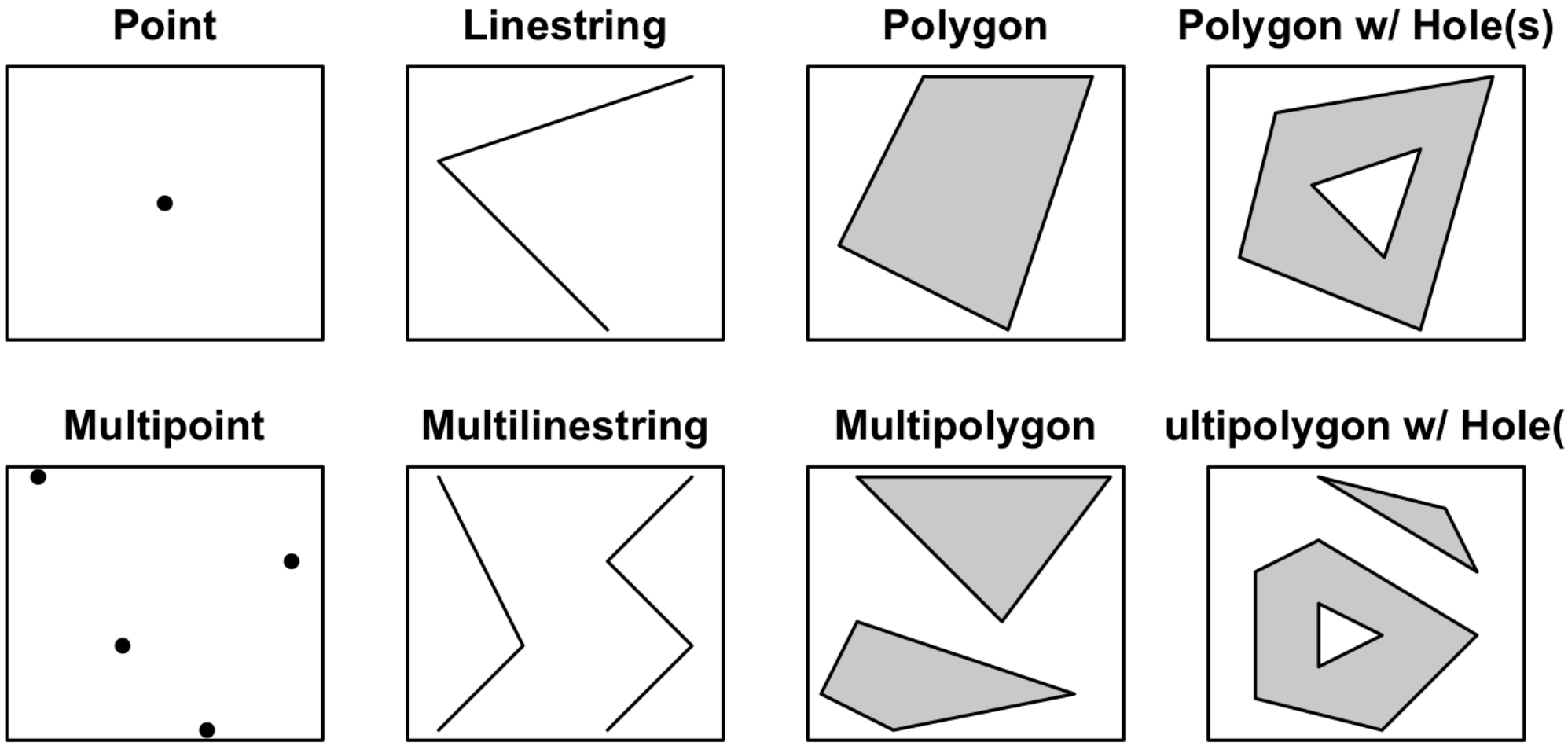
Simple features

A simple feature is a standard way to describe how real-world spatial objects (country, building, tree, road, etc) can be represented by a computer.

The package **`sf`** implements simple features and other spatial functionality using **tidy** principles.

Simple features

Simple features have a geometry type. Common choices are below.



A simple feature object

- Simple features are stored in a data frame, with the geographic information in a column called **`geometry`**.
- Simple features can contain both spatial and non-spatial data.
- Functions for spatial data in **`sf`** begin **`st_`**.

A simple feature object

```
## Simple feature collection with 100 features and 6 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## geographic CRS: NAD27
## First 10 features:
##           name regstrd voted mailed rejectd ml_rqst
## 1         ASHE   19414  8428     NA      NA    2666
## 2    ALLEGHANY    7556  4101     NA      NA     971
## 3        SURRY   46666 23660   4366       7    7088
## 4    CURRITUCK   21803  7536     NA      NA    2472
## 5  NORTHAMPTON   13891  6196    828       2    1441
## 6     HERTFORD   14945  6955     NA      NA    1524
## 7       CAMDEN    8128  3472    416       1     739
## 8        GATES    8294  3105     NA      NA     847
## 9       WARREN   13441  6878     NA      NA    1913
## 10      STOKES   31649 14444   2162       2    3648
##                           geometry
## 1  MULTIPOLYGON (((-81.47276 3...
## 2  MULTIPOLYGON (((-81.23989 3...
## 3  MULTIPOLYGON (((-80.45634 3...
## 4  MULTIPOLYGON (((-76.00897 3...
```

Visualizing spatial data

nc_votes

This data was pulled from the North Carolina Early Voting Statistics website and is current as of 10-28-2020.

The dataset contains the following variables:

- **name**: county name
- **regstrd**: number of registered voters
- **voted**: number of individuals who have voted
- **mailed**: number of mail ballots returned
- **rejectd**: number of mail ballots rejected
- **ml_rqst**: number of mail ballots requested

Getting `sf` objects

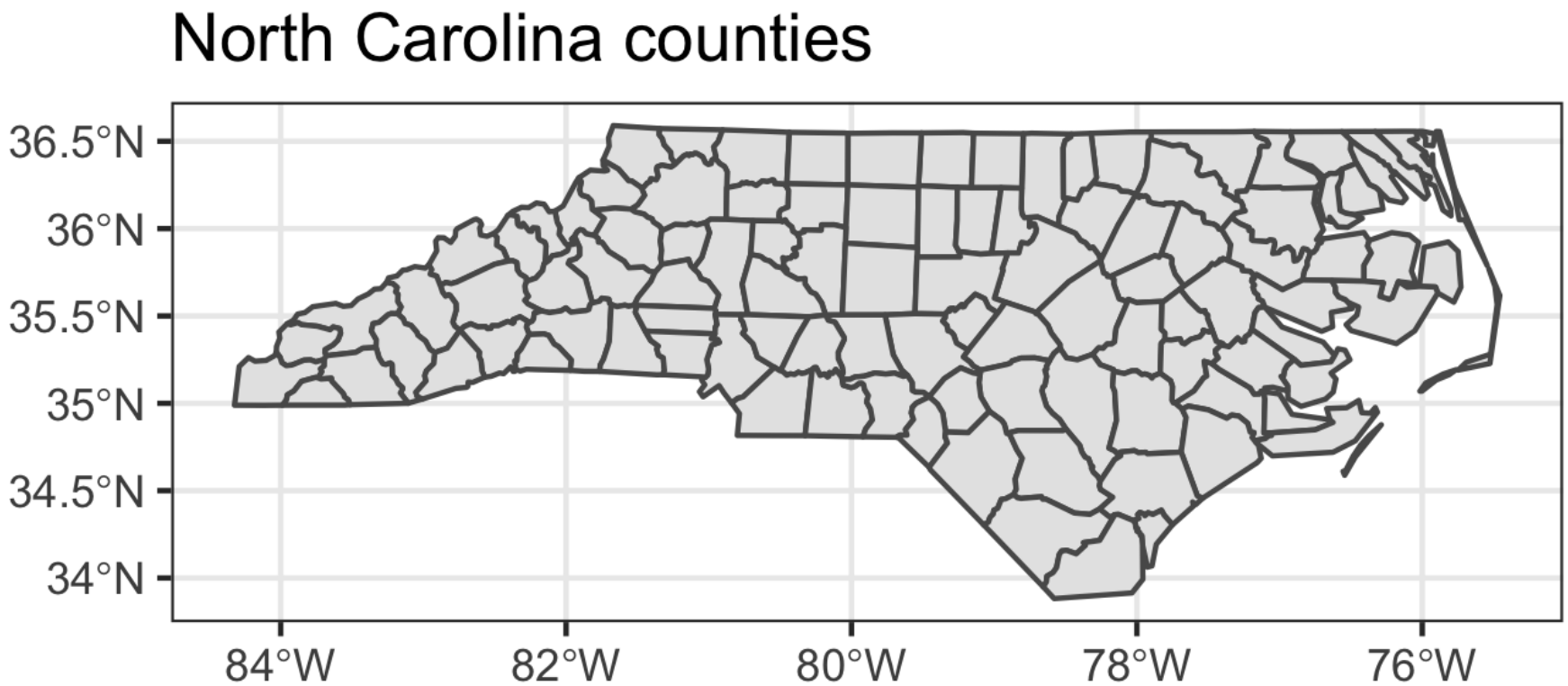
To read simple features from a file or database use the function **`st_read()`**.

```
library(sf)
nc <- st_read("data/nc_votes.shp", quiet = TRUE)
nc
```

```
## Simple feature collection with 100 features and 6 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## geographic CRS: NAD27
## First 10 features:
##           name regstrd voted mailed rejectd ml_rqst
## 1         ASHE   19414  8428     NA      NA    2666
## 2    ALLEGHANY    7556  4101     NA      NA     971
## 3        SURRY   46666 23660   4366       7    7088
## 4    CURRITUCK   21803  7536     NA      NA    2472
## 5  NORTHAMPTON   13891  6196    828       2    1441
## 6     HERTFORD   14945  6955     NA      NA    1524
## 7       CAMDEN    8128  3472    416       1     739
## 8        GATES    8294  3105     NA      NA     847
## 9       WARREN   13441  6878     NA      NA    1913
## 10      STOKES   31649 14444   2162       2    3648
##                          geometry
```

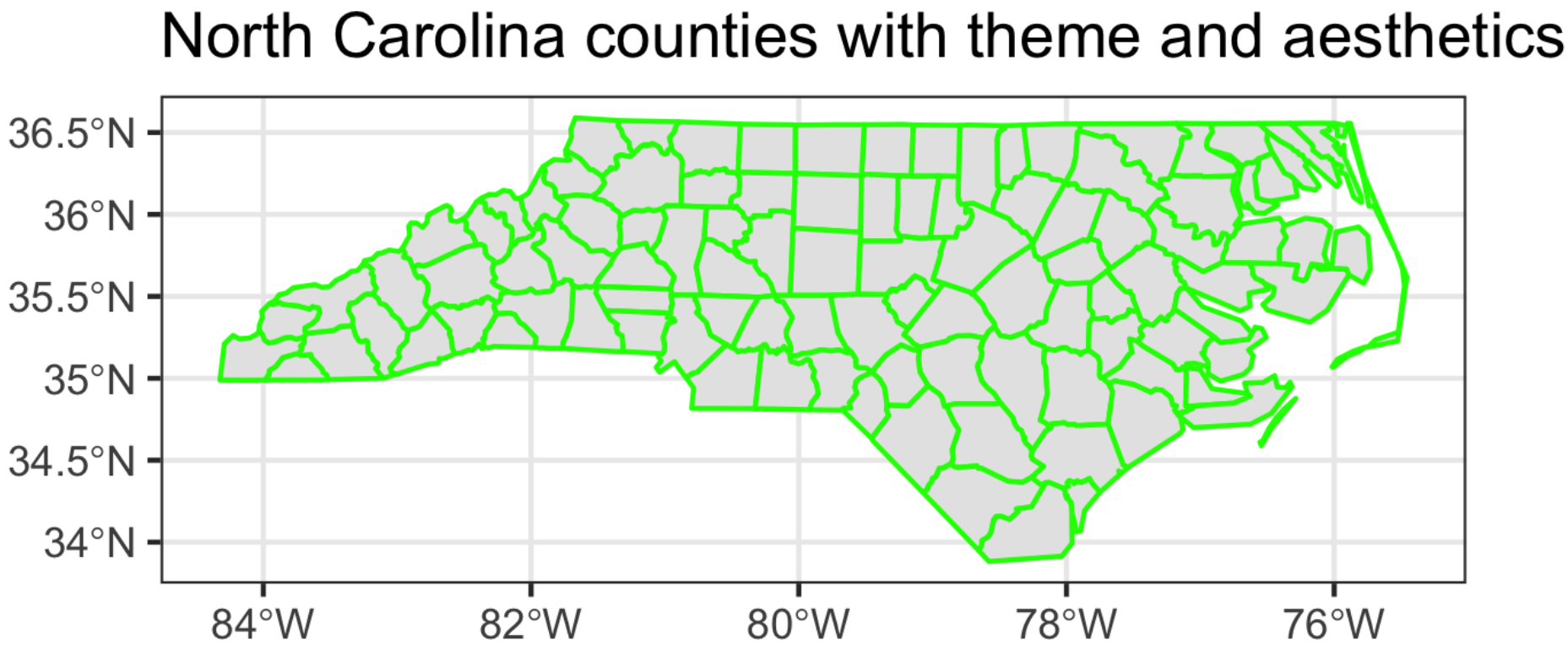
Plotting with `ggplot()`

```
ggplot(nc) +
  geom_sf() +
  labs(title = "North Carolina counties")
```



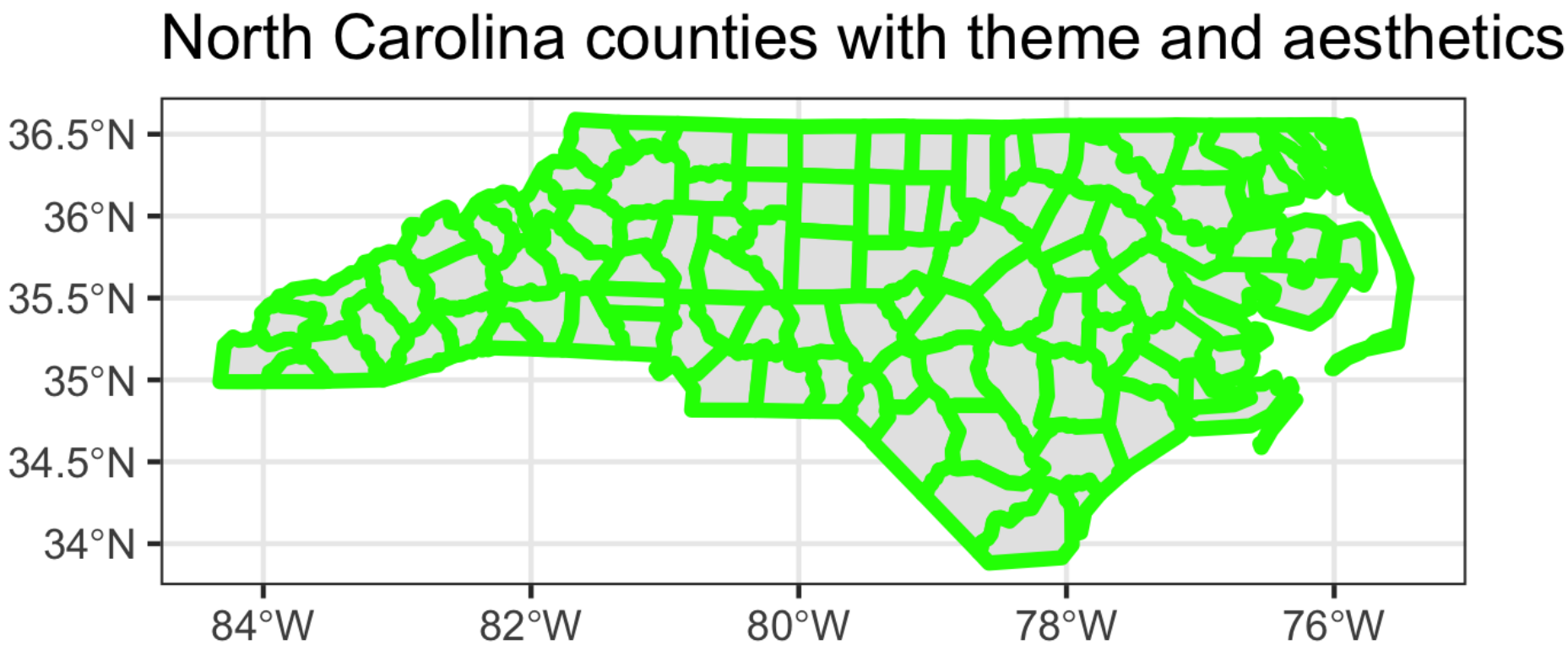
A look at some aesthetics

```
ggplot(nc) +
  geom_sf(color = "green") +
  labs(title = "North Carolina counties with theme and aesthetics")
```



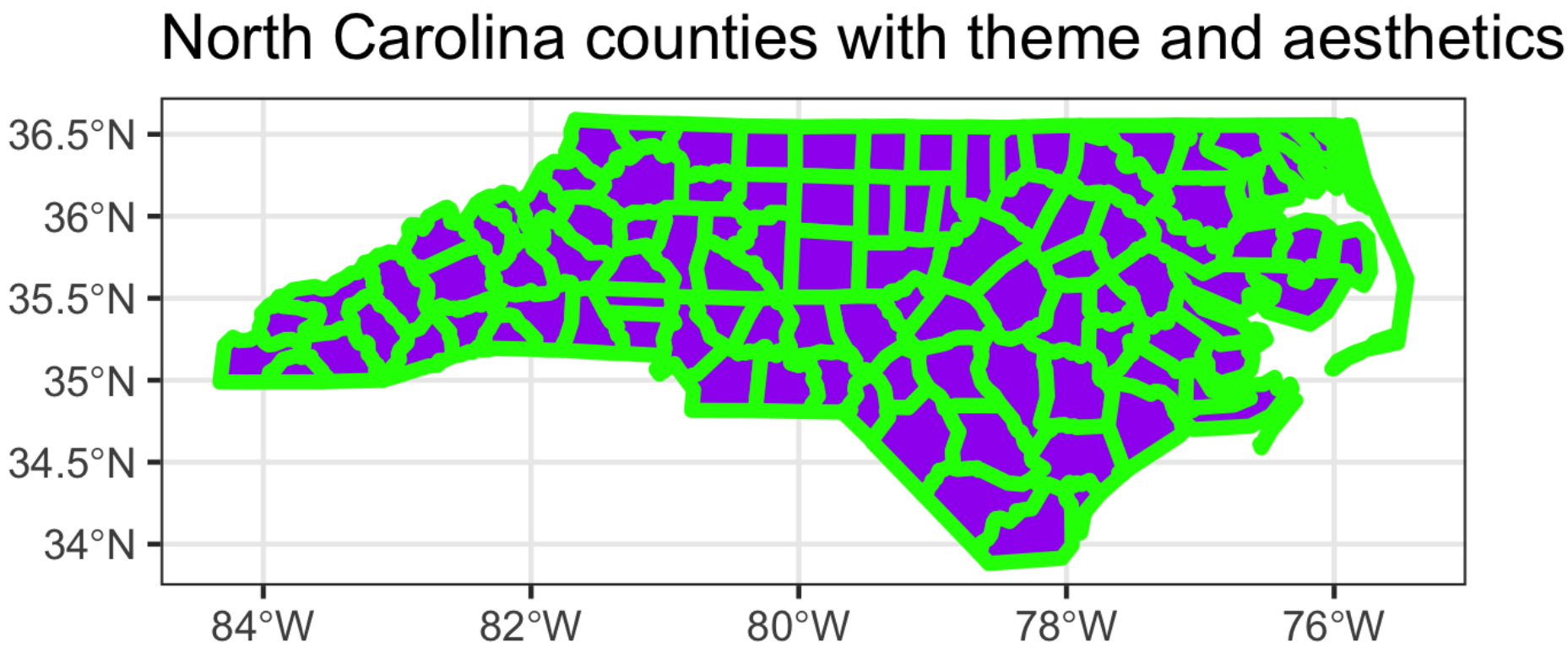
A look at some aesthetics

```
ggplot(nc) +
  geom_sf(color = "green", size = 1.5) +
  labs(title = "North Carolina counties with theme and aesthetics")
```



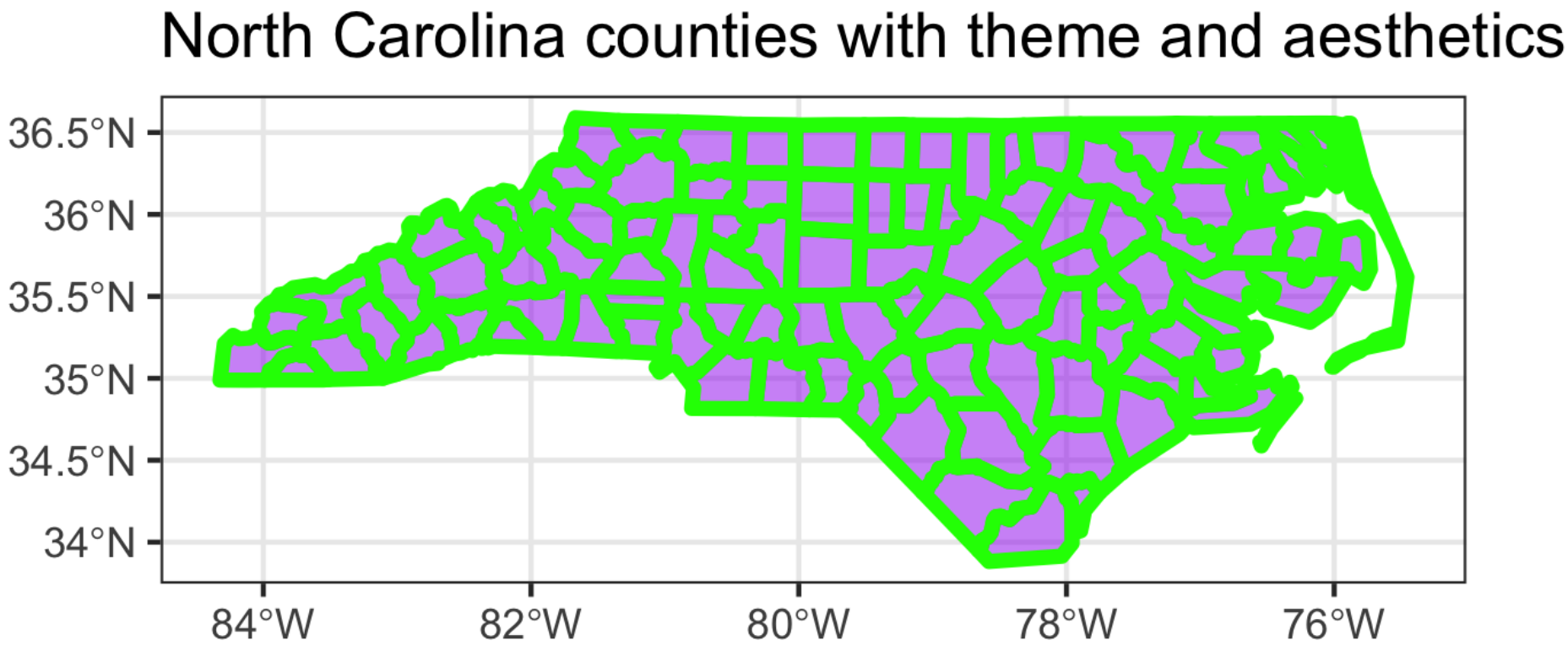
A look at some aesthetics

```
ggplot(nc) +
  geom_sf(color = "green", size = 1.5, fill = "purple") +
  labs(title = "North Carolina counties with theme and aesthetics")
```



A look at some aesthetics

```
ggplot(nc) +
  geom_sf(color = "green", size = 1.5, fill = "purple", alpha = 0.50)
  labs(title = "North Carolina counties with theme and aesthetics")
```

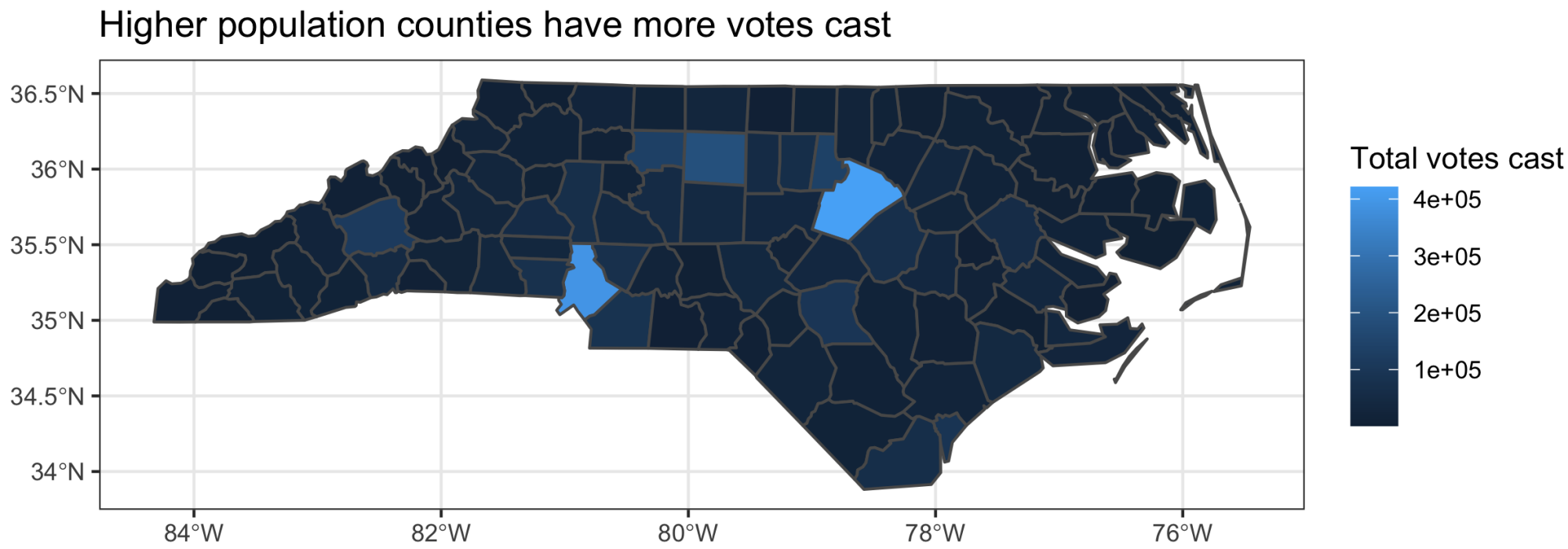


A look back at some of our data

```
## Simple feature collection with 100 features and 6 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## geographic CRS: NAD27
## First 10 features:
##           name regstrd voted mailed rejectd ml_rqst
## 1         ASHE   19414  8428     NA      NA    2666
## 2    ALLEGHANY    7556  4101     NA      NA     971
## 3        SURRY   46666 23660   4366       7    7088
## 4    CURRITUCK   21803  7536     NA      NA    2472
## 5  NORTHAMPTON   13891  6196    828       2    1441
## 6     HERTFORD   14945  6955     NA      NA    1524
## 7       CAMDEN    8128  3472    416       1     739
## 8        GATES    8294  3105     NA      NA     847
## 9       WARREN   13441  6878     NA      NA    1913
## 10      STOKES   31649 14444   2162       2    3648
##                           geometry
## 1  MULTIPOLYGON (((-81.47276 3...
## 2  MULTIPOLYGON (((-81.23989 3...
## 3  MULTIPOLYGON (((-80.45634 3...
## 4  MULTIPOLYGON (((-76.00897 3...
## 5  MULTIPOLYGON (((-77.21767 3...
## 6  MULTIPOLYGON (((-76.74506 3...
## 7  MULTIPOLYGON (((-76.00897 3...
```

Choropleth map

Plot | Code

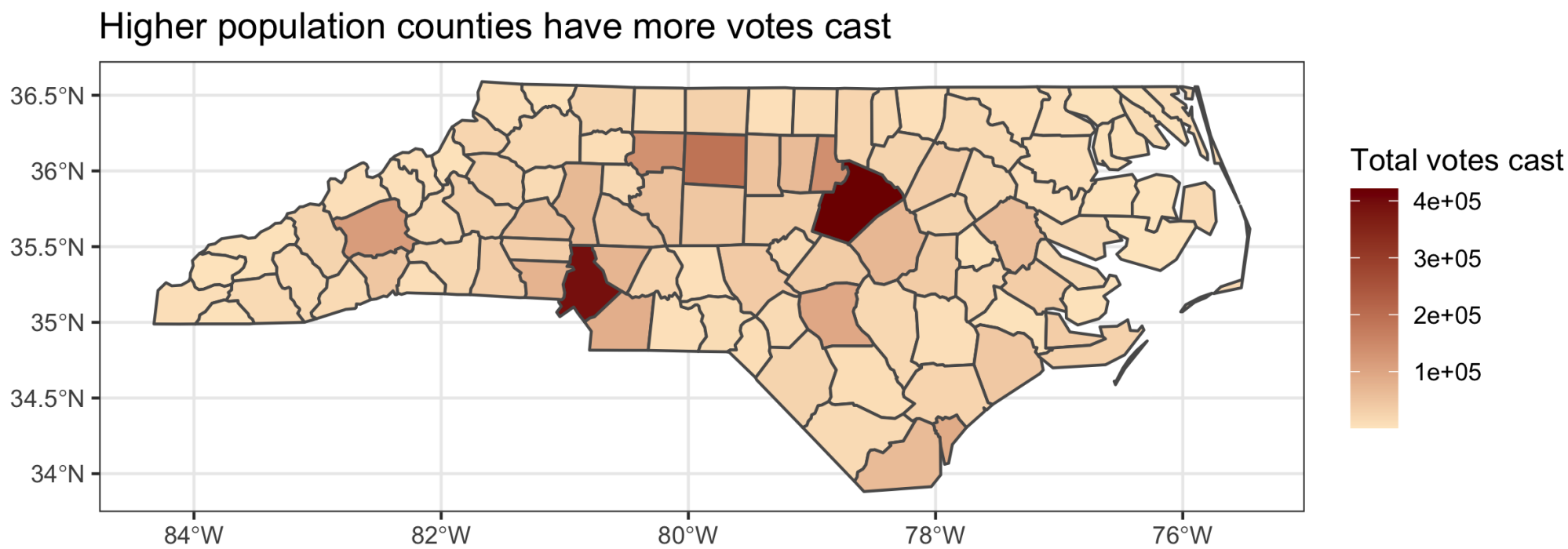


It is sometimes helpful to pick diverging colors, **colorbrewer2** can help.

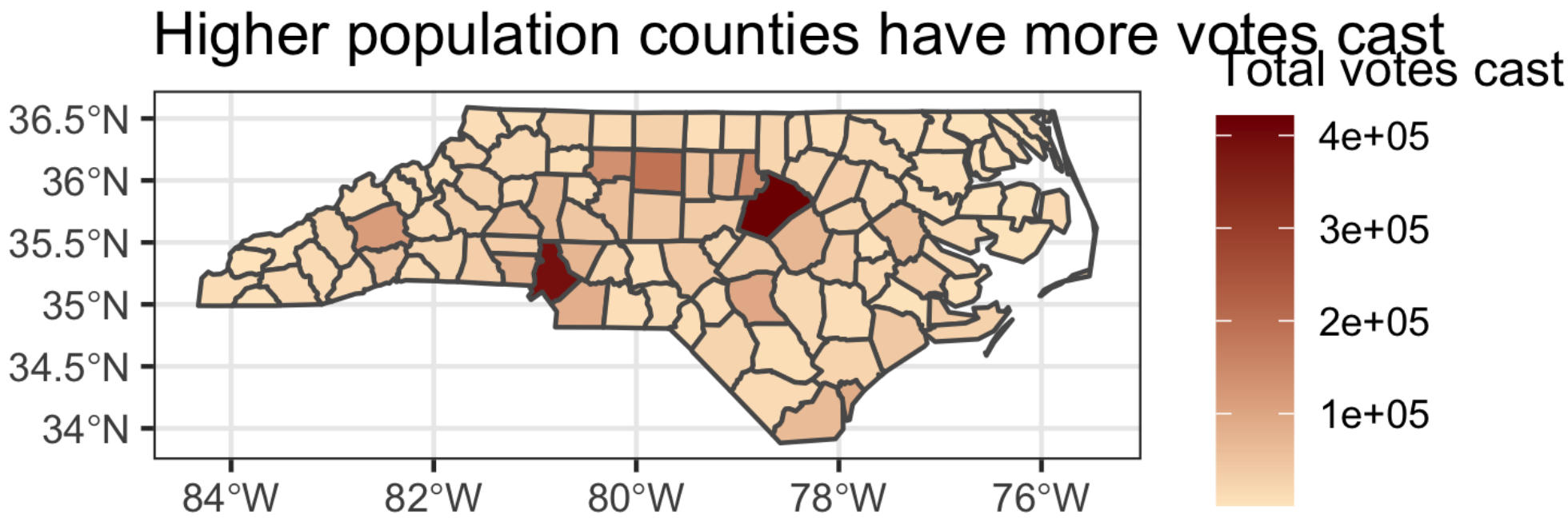
Choropleth map

One way to set fill colors is with **`scale_fill_gradient()`**.

Plot | Code

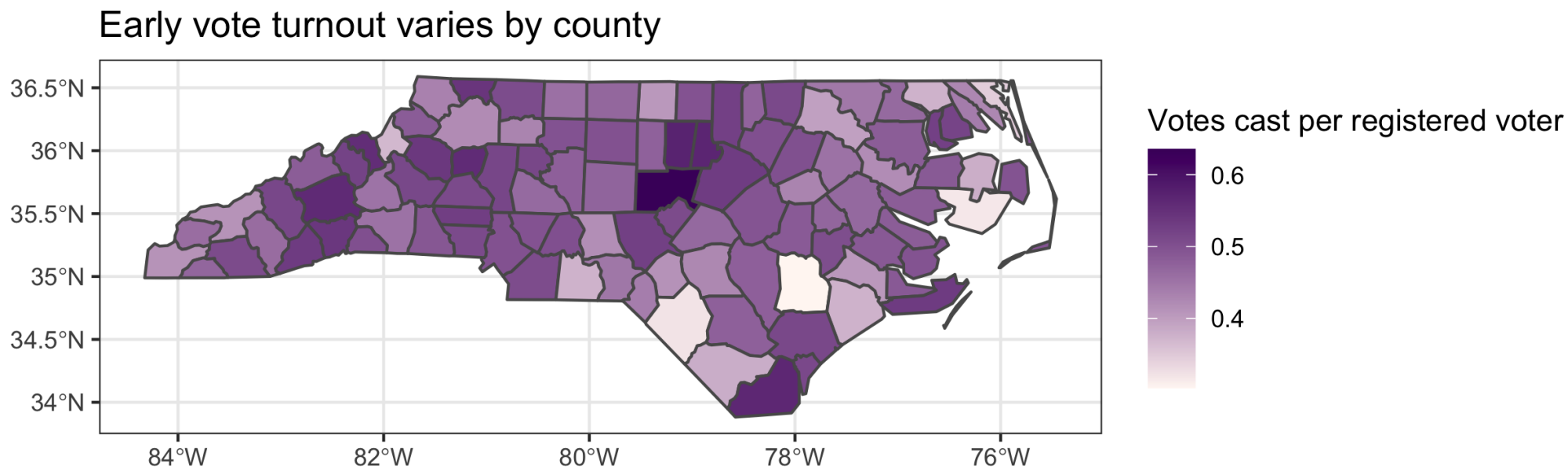


"...it's just a population map!"



Let's make it more informative

Plot | Code



Map layers

Game Lands data

The North Carolina Department of Environment and Natural Resources, Wildlife Resources Commission and the NC Center for Geographic Information and Analysis has a **shapefile data set** available on all public Game Lands in NC.

```
nc_game <- st_read("data/gamelands.shp", quiet = TRUE)
```

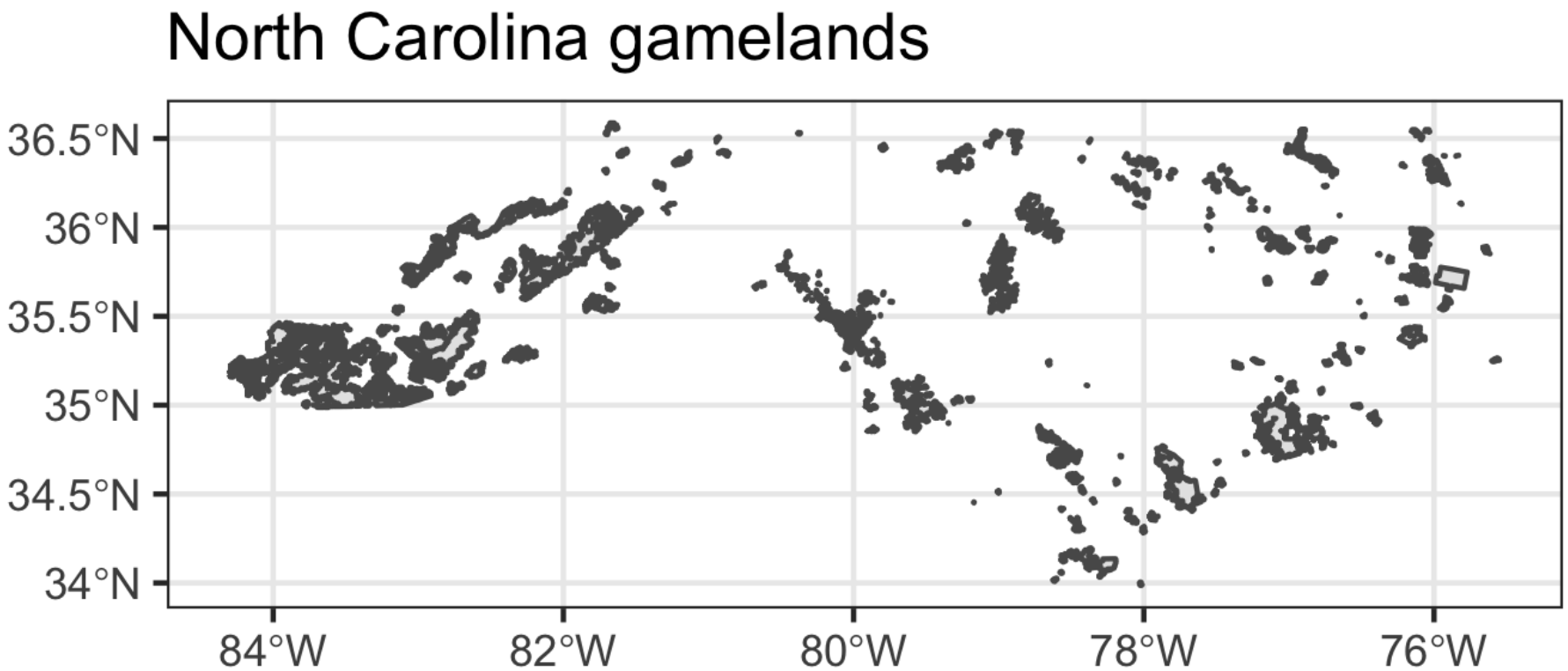
A closer look

```
nc_game
```

```
## Simple feature collection with 94 features and 6 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.29534 ymin: 33.98542 xmax: -75.54947 ymax: 36.58814
## geographic CRS: NAD27
## First 10 features:
##    OBJECTID                   GML_HAB  SUM_ACRES GameLandID Shape__Are
## 1         1                     Alcoa 11395.9471          1   69931121
## 2         2           Alligator River 24439.0891          2  151120825
## 3         3                Angola Bay 34063.4468          3  204400526
## 4         4              Bachelor Bay  2786.2577          4   17219484
## 5         5             Bertie County  3883.7683          5   24044312
## 6         6 Bladen Lakes State Forest 33671.8426          6  202085696
## 7         7              Brinkleyville  1843.8439         92   11511489
## 8         8                   Buckhorn   491.3477         81    3046371
## 9         9                  Buckridge 17965.7187         10  110580903
## 10       10               Buffalo Cove  6630.9453         11   41161465
##    Shape__Len                          geometry
## 1   549030.42 MULTIPOLYGON (((-80.07347 3...
## 2   186792.83 MULTIPOLYGON (((-76.11832 3...
## 3   105421.80 MULTIPOLYGON (((-77.86947 3...
## 4    32891.84 MULTIPOLYGON (((-76.73896 3...
## 5    83468.94 MULTIPOLYGON (((-76.9209 35...
```

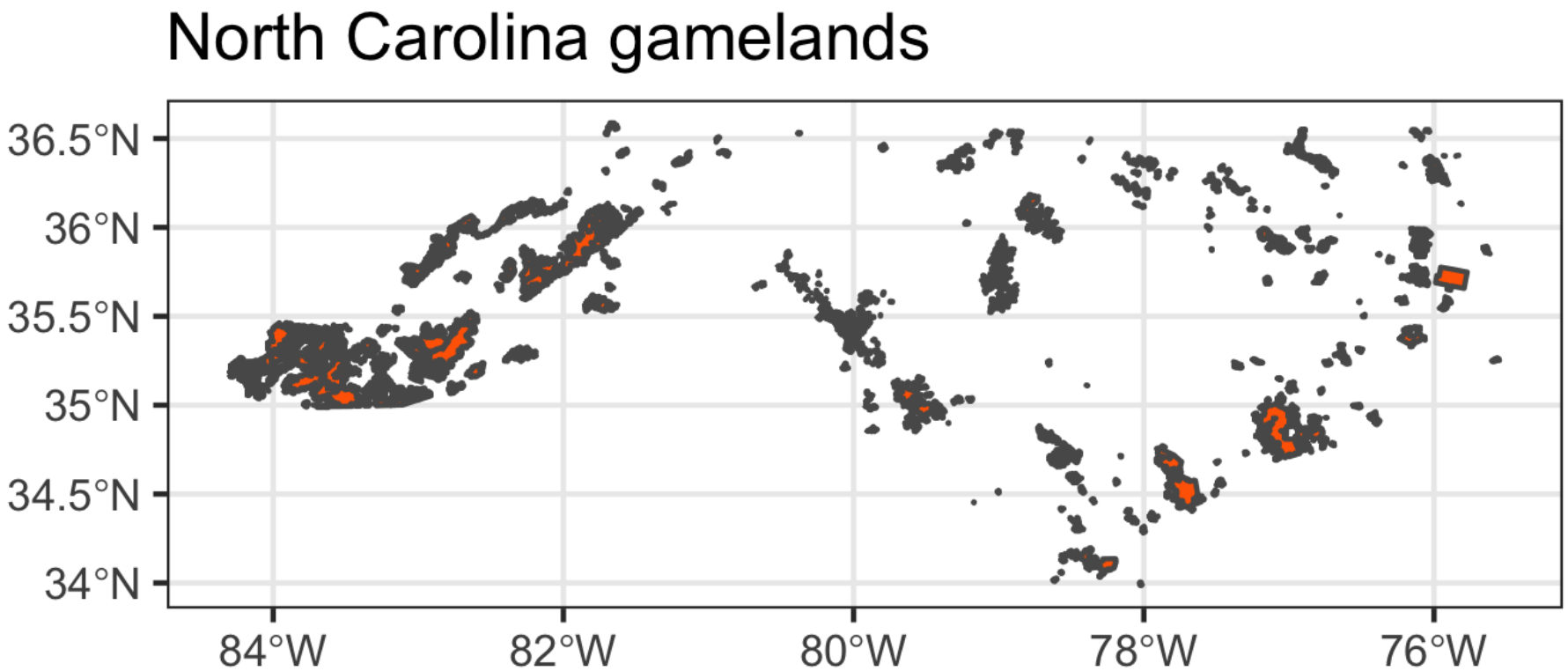
Visualize `nc_game`

```
ggplot(nc_game) +
  geom_sf() +
  labs(title = "North Carolina gamelands")
```



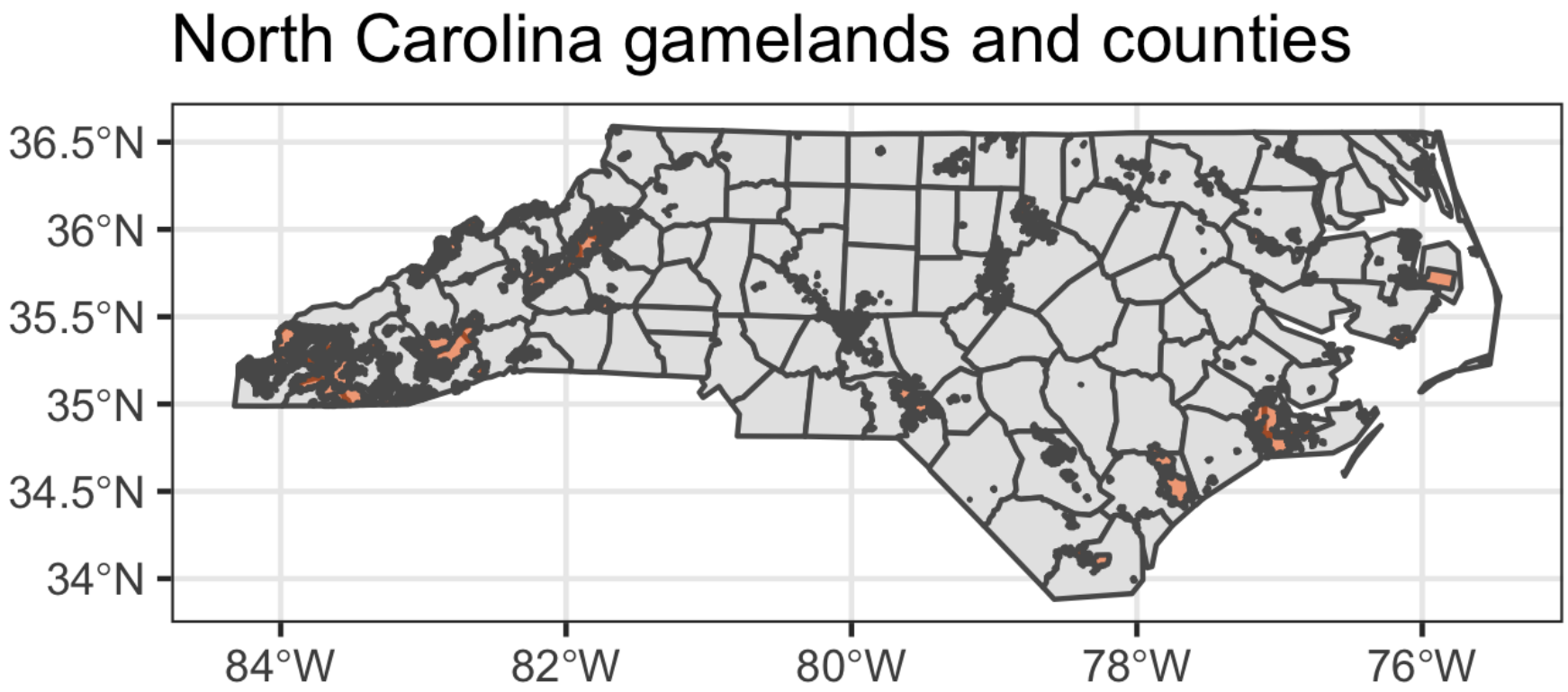
Visualize `nc_game`

```
ggplot(nc_game) +
  geom_sf(fill = "#ff6700") +
  labs(title = "North Carolina gamelands")
```



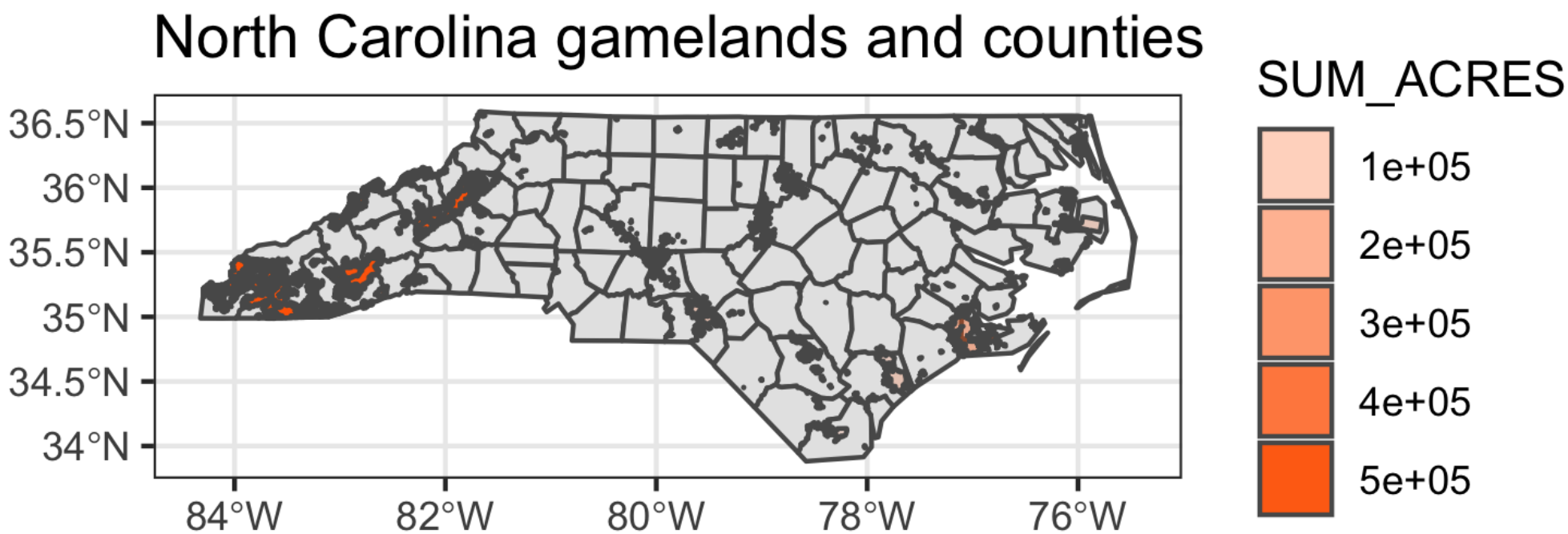
Add layers

```
ggplot(nc) +
  geom_sf() +
  geom_sf(data = nc_game, fill = "#ff6700", alpha = .5) +
  labs(title = "North Carolina gamelands and counties")
```



Add layers and aesthetics

```
ggplot(nc) +
  geom_sf() +
  geom_sf(data = nc_game, aes(alpha = SUM_ACRES), fill = "#ff6700") +
  labs(title = "North Carolina gamelands and counties")
```



Spatial challenges

Challenge #1

Different types of data exist (raster and vector).

Challenge #2

The coordinate reference system (CRS) matters.

```r
Simple feature collection with 100 features and 1 field
geometry type:  MULTIPOLYGON
dimension:      XY
bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
epsg (SRID):    4326
proj4string:    +proj=longlat +datum=WGS84 +no_defs
# A tibble: 100 x 2
  NAME                                                    geometry
  <chr>                                                <MULTIPOLYGON [°]>
1 Ashe          (((-81.47276 36.23436, -81.54084 36.27251,  -...
```

Challenge #3

Manipulating spatial data objects is similar, but not identical to manipulating data frames.

Note the core data-wrangling functions from **`dplyr`** do work.

dplyr + sf

select

```
nc %>%
  select(name, regstrd, voted)
```

```
## Simple feature collection with 100 features and 3 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.589
## geographic CRS: NAD27
## First 10 features:
##           name regstrd voted                       geometry
## 1         ASHE   19414  8428 MULTIPOLYGON (((-81.47276 3...
## 2    ALLEGHANY    7556  4101 MULTIPOLYGON (((-81.23989 3...
## 3        SURRY   46666 23660 MULTIPOLYGON (((-80.45634 3...
## 4    CURRITUCK   21803  7536 MULTIPOLYGON (((-76.00897 3...
## 5  NORTHAMPTON   13891  6196 MULTIPOLYGON (((-77.21767 3...
## 6     HERTFORD   14945  6955 MULTIPOLYGON (((-76.74506 3...
## 7       CAMDEN    8128  3472 MULTIPOLYGON (((-76.00897 3...
## 8        CATES    8294  3105 MULTIPOLYGON (((-76.56251 3...
```

filter

```
nc %>%
  filter(regstrd > 100000)
```

```
## Simple feature collection with 20 features and 6 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -82.88111 ymin: 33.88199 xmax: -77.10377 ymax: 36.25
## geographic CRS: NAD27
## First 10 features:
##        name regstrd  voted mailed rejectd ml_rqst
## 1   FORSYTH  270818 134770  35664      75   67472
## 2  GUILFORD  381797 190530  42825     785   76615
## 3  ALAMANCE  110127  52434  12788      19   22091
## 4    ORANGE  111765  64016  22859      55   36560
## 5    DURHAM  243045 138264  41767     348   70046
## 6      WAKE  791821 421180 138483     781  244538
## 7   IREDELL  130013  67128  14775       2   22390
## 8  DAVIDSON  112872  54040  10012      87   16240
```

summarize

```
nc %>%
  summarize(mean_registered  = mean(regstrd),
            mean_voted = median(voted))
```

```
## Simple feature collection with 1 feature and 2 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.589
## geographic CRS: NAD27
##   mean_registered mean_voted                       geometry
## 1        73183.36      16217 MULTIPOLYGON (((-77.96073 3...
```

Geometries are "sticky"

The geometry is kept until it is deliberated dropped using **`st_drop_geometry`**.

Geometries are "sticky"

The geometry is kept until it is deliberated dropped using **`st_drop_geometry`**.

```
nc %>%
  select(name, regstrd) %>%
  filter(regstrd > 100000) %>%
  st_drop_geometry()
```

```
##          name regstrd
## 1      FORSYTH  270818
## 2    GUILFORD  381797
## 3    ALAMANCE  110127
## 4      ORANGE  111765
## 5      DURHAM  243045
## 6        WAKE  791821
## 7     IREDELL  130013
## 8    DAVIDSON  112872
## 9        PITT  122925
```

References

- North Carolina Early Voting Statistics
- Simple Features for R vignette
- mapview vignette
- Coordinate Reference Systems in R
- Geocomputation with R