Spatial Data

Statistical Computing & Programming

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Supplementary materials

Companion videos

- Spatial data lecture preview
- Introduction to spatial data
- Spatial data in R with package `sf`
- Visualizing spatial data
- Map layers and CRS
- Wrangling spatial data

Additional resources

- Simple Features for R vignettes
- CRS in R by Melanie Frazier
- Leaflet for R

Introduction

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
#>    <int> <int> <int>    <int>          <int>     <dbl>    <int>
#>  1  2013     1     1      517            515         2      830
#>  2  2013     1     1      533            529         4      850
#>  3  2013     1     1      542            540         2      923
#>  4  2013     1     1      544            545        -1     1004
#>  5  2013     1     1      554            600        -6      812
#>  6  2013     1     1      554            558        -4      740
#>  7  2013     1     1      555            600        -5      913
#>  8  2013     1     1      557            600        -3      709
#>  9  2013     1     1      557            600        -3      838
#> 10  2013     1     1      558            600        -2      753
#> # … with 336,766 more rows, and 12 more variables: sched_arr_time <int>,
#> #   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>
```

A simple features object:

```
#> Simple feature collection with 100 features and 5 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
#> epsg (SRID):    4267
#> proj4string:    +proj=longlat +datum=NAD27 +no_defs
#> First 10 features:
#>     AREA PERIMETER CNTY_ CNTY_ID        NAME
#> 1  0.114     1.442  1825    1825        Ashe
#> 2  0.061     1.231  1827    1827   Alleghany
#> 3  0.143     1.630  1828    1828       Surry
#> 4  0.070     2.968  1831    1831   Currituck
#> 5  0.153     2.206  1832    1832 Northampton
#> 6  0.097     1.670  1833    1833    Hertford
#> 7  0.062     1.547  1834    1834      Camden
#> 8  0.091     1.284  1835    1835       Gates
#> 9  0.118     1.421  1836    1836      Warren
#> 10 0.124     1.428  1837    1837      Stokes
#>                          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...
#> 8  MULTIPOLYGON (((-76.56251 3...
#> 9  MULTIPOLYGON (((-78.30876 3...
#> 10 MULTIPOLYGON (((-80.02567 3...
```

Another simple features object:

```
#> Simple feature collection with 94 features and 1 field
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: 127456.7 ymin: 26560.42 xmax: 923523.8 ymax: 318097.4
#> epsg (SRID):    32119
#> proj4string:    +proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333333334 +lat_0=33.75 +lon_0=-79 +x_
#> # A tibble: 94 x 2
#>    GML_HAB                                                      geometry
#>    <chr>                                                <MULTIPOLYGON [m]>
#>  1 Alcoa              (((512096.2 183241.7, 512185.7 183203.4, 512226 1831…
#>  2 Alligator River    (((869633.1 244541.9, 869739.4 243987.6, 869762.7 24…
#>  3 Angola Bay         (((721333.1 107161.1, 721374.7 107222.9, 721474 1073…
#>  4 Bachelor Bay       (((813742.2 238618.7, 813730 238603.2, 813693.8 2385…
#>  5 Bertie County      (((797133.8 247034.5, 797119.5 247030, 797112.2 2470…
#>  6 Bladen Lakes Stat… (((658970.6 95406.32, 660025.1 94245.76, 659839.4 94…
#>  7 Brinkleyville      (((714741 276970.3, 714623.9 276970, 714622.1 277000…
#>  8 Buckhorn           (((589723.7 253224.6, 589568.5 252937.2, 589689.8 25…
#>  9 Buckridge          (((871137.4 219894.9, 871124.9 219827.8, 871124.2 21…
#> 10 Buffalo Cove       (((381445.9 260375.4, 381574.9 259668.3, 381915 2597…
#> # … with 84 more rows
```

Spatial data plotting needs care

Can we combine the two plots?

We can, but more care is needed.

Spatial data challenges

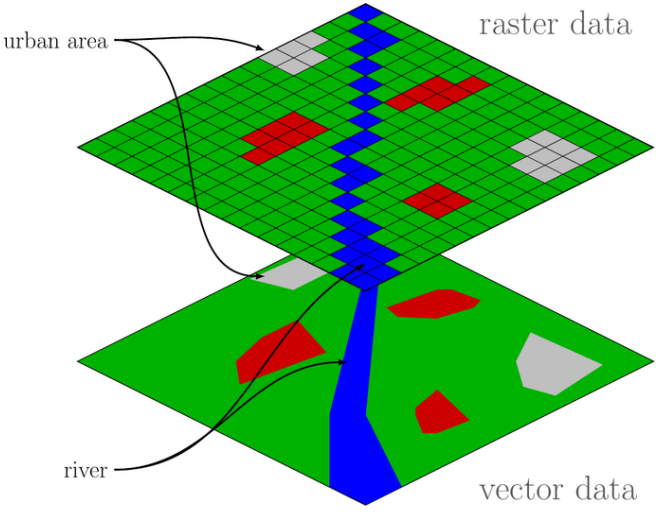
1. Different data types exist.
2. Special attention must be given to the coordinate reference system (CRS).
3. Manipulating spatial data objects is similar but not identical to manipulating data frame objects.

Spatial data and R

Analysis of spatial data in R

- Package `raster` contains classes and tools for handling spatial raster data.

- Package `sf` combines the functionality of `sp`, `rgdal`, and `rgeos` into a single package based on tidy simple features.



Whether or not you use vector or raster data depends on the type of problem and the data source. Our focus will be on vector data and package `sf`.

Source: https://commons.wikimedia.org/wiki/File:Raster_vector_tikz.png

Installing package `sf`

From https://r-spatial.github.io/sf/index.html

Windows

Installing `sf` from source works under windows when Rtools is installed. This downloads the system requirements from rwinlib.

MacOS

```
brew install pkg-config
brew install gdal
```

Once gdal is installed, you will be able to install sf package from source in R.

Linux

For Unix-alikes, GDAL (>= 2.0.1), GEOS (>= 3.4.0) and Proj.4 (>= 4.8.0) are required.

Features and simple features

- A **feature** is a thing or object in the real world: a house, a city, a park, a forest, etc.
- A **simple feature** as defined by OpenGIS Abstract specification is to have both spatial and non-spatial attributes. Spatial attributes are geometry valued, and simple features are based on 2D geometry with linear interpolation between vertices.

```
#> 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,  -...
#>  2 Alleghany   (((-81.23989 36.36536, -81.24069 36.37942,  -...
```

Simple features examples

Objects `sf` and `sfc`

```
nc <- st_read(system.file("shape/nc.shp", package = "sf"), quiet = TRUE)
```

```
nc
```

```
#> Simple feature collection with 100 features and 14 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
#> epsg (SRID):    4267
#> proj4string:    +proj=longlat +datum=NAD27 +no_defs
#> First 10 features:
#>     AREA PERIMETER CNTY_ CNTY_ID        NAME  FIPS FIPSNO CRESS_ID BIR74
#> 1  0.114     1.442  1825    1825        Ashe 37009  37009        5  1091
#> 2  0.061     1.231  1827    1827   Alleghany 37005  37005        3   487
#> 3  0.143     1.630  1828    1828       Surry 37171  37171       86  3188
#> 4  0.070     2.968  1831    1831   Currituck 37053  37053       27   508
#> 5  0.153     2.206  1832    1832 Northampton 37131  37131       66  1421
#> 6  0.097     1.670  1833    1833    Hertford 37091  37091       46  1452
#> 7  0.062     1.547  1834    1834      Camden 37029  37029       15   286
#> 8  0.091     1.284  1835    1835       Gates 37073  37073       37   420
#> 9  0.118     1.421  1836    1836      Warren 37185  37185       93   968
#> 10 0.124     1.428  1837    1837      Stokes 37169  37169       85  1612
#>    SID74 NWBIR74 BIR79 SID79 NWBIR79                       geometry
#> 1      1      10  1364     0      19 MULTIPOLYGON (((-81.47276 3...
#> 2      0      10   542     3      12 MULTIPOLYGON (((-81.23989 3...
#> 3      5     208  3616     6     260 MULTIPOLYGON (((-80.45634 3...
#> 4      1     123   830     2     145 MULTIPOLYGON (((-76.00897 3...
#> 5      9    1066  1606     3    1197 MULTIPOLYGON (((-77.21767 3...
#> 6      7     954  1838     5    1237 MULTIPOLYGON (((-76.74506 3...
#> 7      0     115   350     2     139 MULTIPOLYGON (((-76.00897 3...
#> 8      0     254   594     2     371 MULTIPOLYGON (((-76.56251 3...
#> 9      4     748  1190     2     844 MULTIPOLYGON (((-78.30876 3...
```

```
attributes(nc)
```

```
#> $names
#>  [1] "AREA"      "PERIMETER" "CNTY_"     "CNTY_ID"   "NAME"
#>  [6] "FIPS"      "FIPSNO"    "CRESS_ID"  "BIR74"     "SID74"
#> [11] "NWBIR74"   "BIR79"     "SID79"     "NWBIR79"   "geometry"
#>
#> $row.names
#>   [1]   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17
#>  [18]  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
#>  [35]  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51
#>  [52]  52  53  54  55  56  57  58  59  60  61  62  63  64  65  66  67  68
#>  [69]  69  70  71  72  73  74  75  76  77  78  79  80  81  82  83  84  85
#>  [86]  86  87  88  89  90  91  92  93  94  95  96  97  98  99 100
#>
#> $class
#> [1] "sf"         "data.frame"
#>
#> $sf_column
#> [1] "geometry"
#>
#> $agr
#>      AREA PERIMETER     CNTY_   CNTY_ID      NAME      FIPS    FIPSNO
#>      <NA>      <NA>      <NA>      <NA>      <NA>      <NA>      <NA>
#>  CRESS_ID     BIR74     SID74   NWBIR74     BIR79     SID79   NWBIR79
#>      <NA>      <NA>      <NA>      <NA>      <NA>      <NA>      <NA>
#> Levels: constant aggregate identity
```

```
nc_polygons <- st_geometry(nc)
nc_polygons
```

```
#> Geometry set for 100 features
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
#> epsg (SRID):    4267
#> proj4string:    +proj=longlat +datum=NAD27 +no_defs
#> First 5 geometries:
```

```
#> Geometry set for 100 features
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 3
#> epsg (SRID):    4267
#> proj4string:    +proj=longlat +datum=NAD27 +no_defs
#> First 5 geometries:
#> MULTIPOLYGON (((-81.47276 36.23436, -81.54084 3...
#> MULTIPOLYGON (((-81.23989 36.36536, -81.24069 3...
#> MULTIPOLYGON (((-80.45634 36.24256, -80.47639 3...
#> MULTIPOLYGON (((-76.00897 36.3196, -76.01735 36...
#> MULTIPOLYGON (((-77.21767 36.24098, -77.23461 3...
```

```
attributes(nc_polygons)
```

```
#> $n_empty
#> [1] 0
#>
#> $crs
#> Coordinate Reference System:
#>   EPSG: 4267
#>   proj4string: "+proj=longlat +datum=NAD27 +no_defs"
#>
#> $class
#> [1] "sfc_MULTIPOLYGON" "sfc"
#>
#> $precision
#> [1] 0
#>
#> $bbox
#>      xmin      ymin      xmax      ymax
#> -84.32385  33.88199 -75.45698  36.58965
```

We see that `nc` has a class attribute `sf`, and object `nc_polygons` has a class attribute `sfc`. What methods are available?

```
methods(class = "sf")
```

```
#>  [1] [                    [[<-                 $<-
#>  [4] aggregate            anti_join            arrange
#>  [7] as.data.frame        cbind                coerce
#> [10] dbDataType           dbWriteTable         distinct
#> [13] filter               full_join            gather
#> [16] group_by             group_map            group_split
#> [19] identify             initialize           inner_join
#> [22] left_join            mapView              merge
#> [25] mutate               nest                 plot
#> [28] print                rbind                rename
#> [31] right_join           sample_frac          sample_n
#> [34] select               semi_join            separate_rows
#> [37] separate             show                 slice
#> [40] slotsFromS3          spread               st_agr
#> [43] st_agr<-             st_area              st_as_sf
#> [46] st_bbox              st_boundary          st_buffer
#> [49] st_cast              st_centroid          st_collection_extract
#> [52] st_convex_hull       st_coordinates       st_crop
#> [55] st_crs               st_crs<-             st_difference
#> [58] st_geometry          st_geometry<-        st_interpolate_aw
#> [61] st_intersection      st_intersects        st_is
#> [64] st_join              st_line_merge        st_nearest_points
#> [67] st_node              st_normalize         st_point_on_surface
#> [70] st_polygonize        st_precision         st_segmentize
#> [73] st_set_precision     st_simplify          st_snap
#> [76] st_sym_difference    st_transform         st_triangulate
#> [79] st_union             st_voronoi           st_wrap_dateline
#> [82] st_write             st_zm                summarise
#> [85] transmute            ungroup              unite
#> [88] unnest
```

```
methods(class = "sfc")
```

```
#>  [1] [                     [<-                   as.data.frame
#>  [4] c                     coerce                format
#>  [7] fortify               identify              initialize
#> [10] mapView               obj_sum               Ops
#> [13] print                 rep                   scale_type
#> [16] show                  slotsFromS3           st_area
#> [19] st_as_binary          st_as_grob            st_as_sf
#> [22] st_as_text            st_bbox               st_boundary
#> [25] st_buffer             st_cast               st_centroid
#> [28] st_collection_extract st_convex_hull        st_coordinates
#> [31] st_crop               st_crs                st_crs<-
#> [34] st_difference         st_geometry           st_intersection
#> [37] st_intersects         st_is                 st_line_merge
#> [40] st_nearest_points     st_node               st_normalize
#> [43] st_point_on_surface   st_polygonize         st_precision
#> [46] st_segmentize         st_set_precision      st_simplify
#> [49] st_snap               st_sym_difference     st_transform
#> [52] st_triangulate        st_union              st_voronoi
#> [55] st_wrap_dateline      st_write              st_zm
#> [58] str                   summary               type_sum
#> see '?methods' for accessing help and source code
```

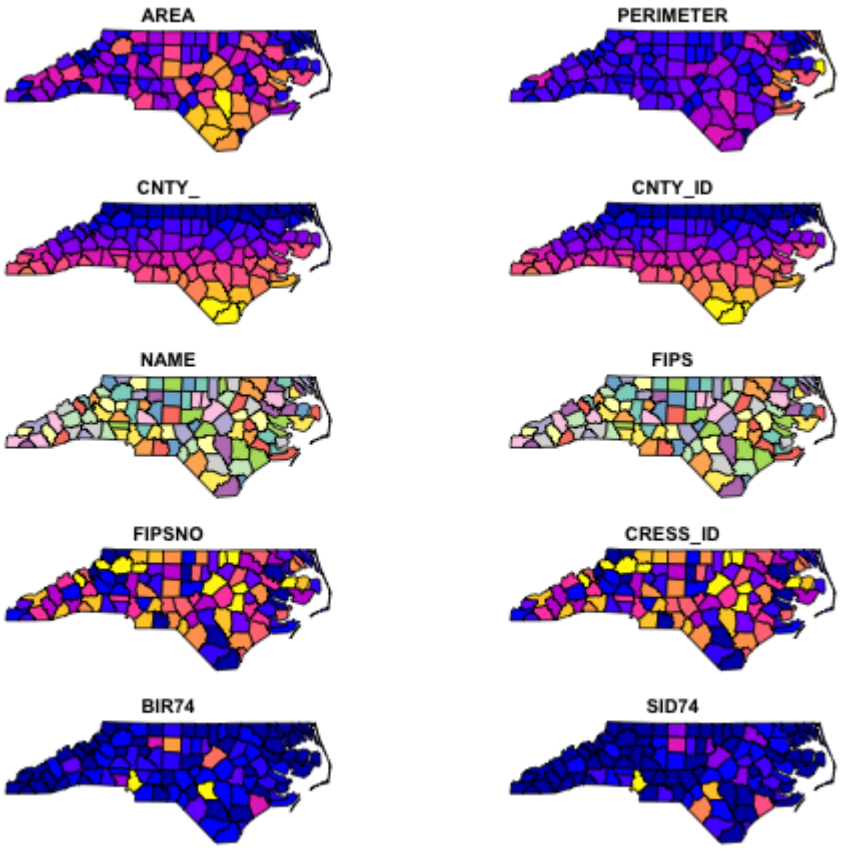
Reading and writing spatial data

- `st_read()` / `st_write()`, Shapefile, GeoJSON, KML, ...
- `st_as_sfc()`
- `st_as_text()`, well-known text format
- `st_as_binary()`, well-known binary format

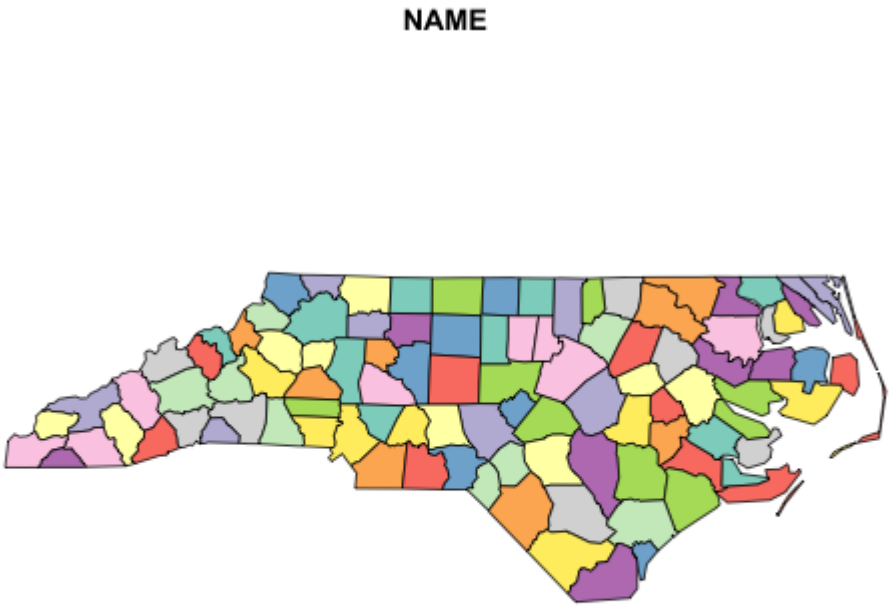
See https://r-spatial.github.io/sf/articles/sf2.html for the full set of driver availability.

Plotting with `plot()`

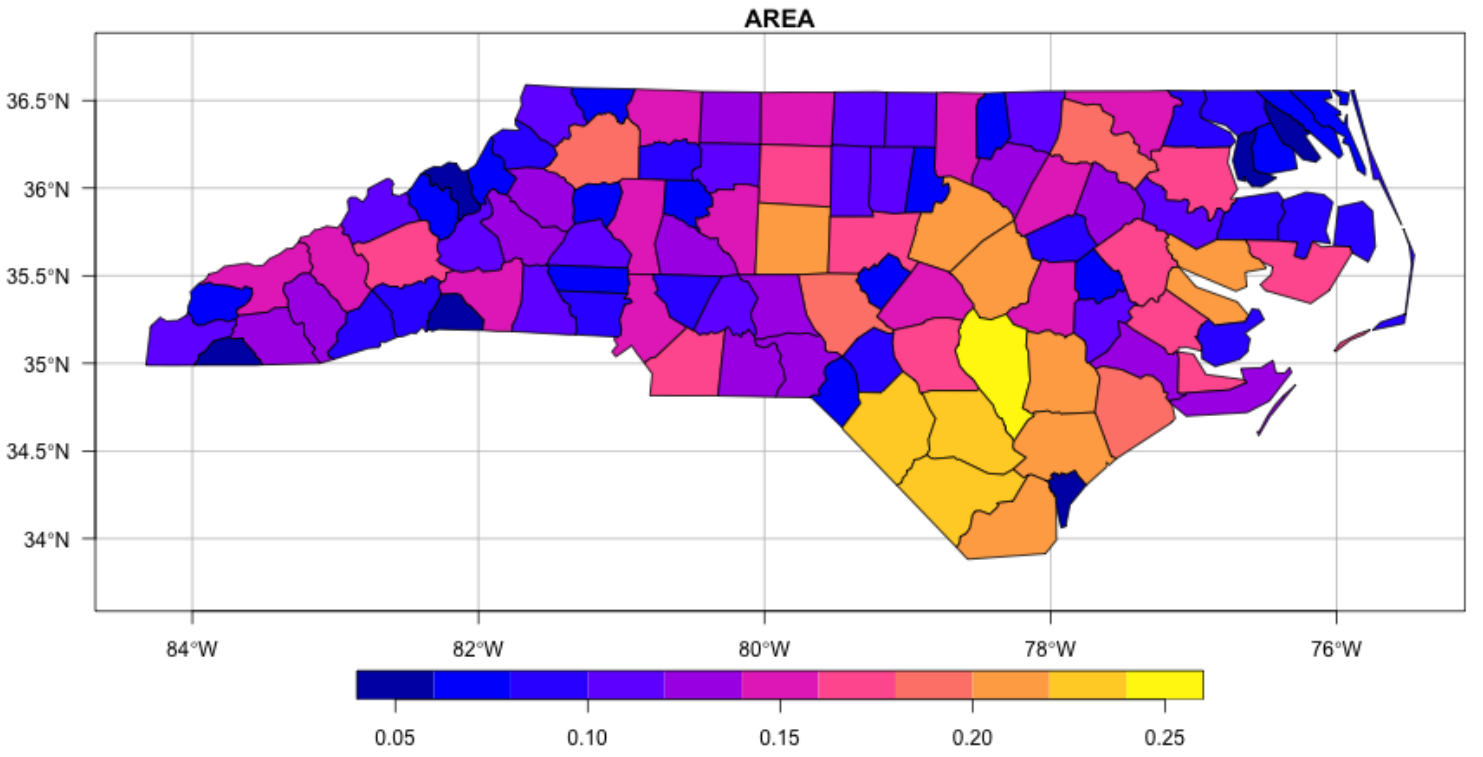
```
plot(nc)
```



```
plot(nc["NAME"])
```



```
par(oma=c(0,2,0,0))
plot(nc["AREA"], graticule = TRUE, axes = TRUE, las = 1)
```



What is happening with `[` and the `sf` object?

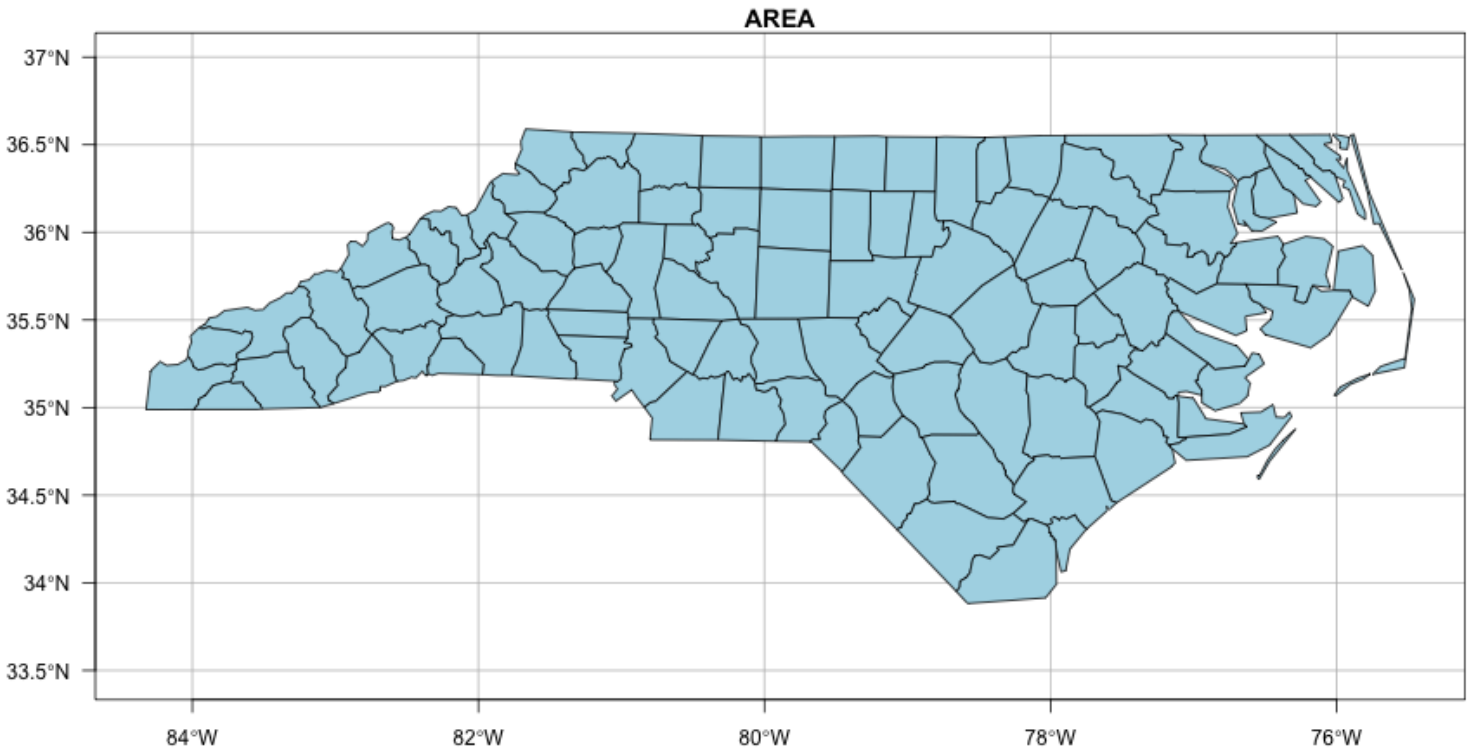
```
nc["AREA"]
```

```
#> 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):    4267
#> proj4string:    +proj=longlat +datum=NAD27 +no_defs
#> First 10 features:
#>     AREA                       geometry
#> 1  0.114 MULTIPOLYGON (((-81.47276 3...
#> 2  0.061 MULTIPOLYGON (((-81.23989 3...
#> 3  0.143 MULTIPOLYGON (((-80.45634 3...
#> 4  0.070 MULTIPOLYGON (((-76.00897 3...
#> 5  0.153 MULTIPOLYGON (((-77.21767 3...
#> 6  0.097 MULTIPOLYGON (((-76.74506 3...
#> 7  0.062 MULTIPOLYGON (((-76.00897 3...
#> 8  0.091 MULTIPOLYGON (((-76.56251 3...
#> 9  0.118 MULTIPOLYGON (((-78.30876 3...
#> 10 0.124 MULTIPOLYGON (((-80.02567 3...
```

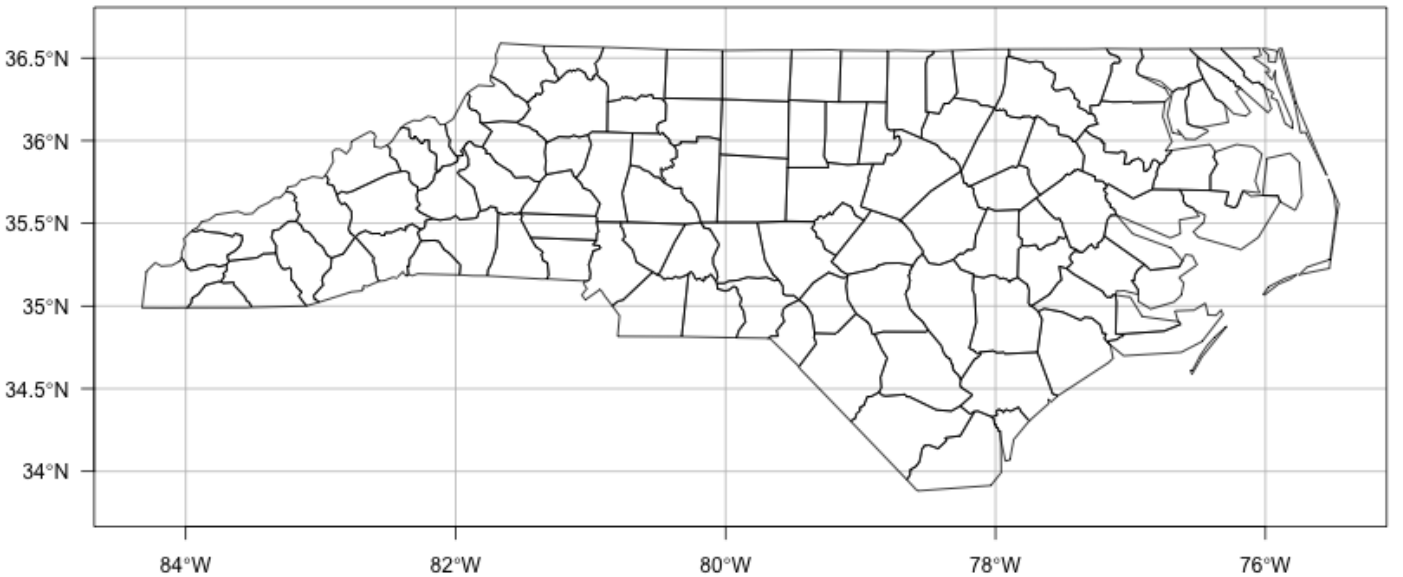
```
nc$AREA
```

```
#>   [1] 0.114 0.061 0.143 0.070 0.153 0.097 0.062 0.091 0.118 0.124 0.114
#>  [12] 0.153 0.143 0.109 0.072 0.190 0.053 0.199 0.081 0.063 0.044 0.064
#>  [23] 0.086 0.128 0.108 0.170 0.111 0.180 0.104 0.077 0.142 0.059 0.131
#>  [34] 0.122 0.080 0.118 0.219 0.118 0.155 0.069 0.066 0.145 0.134 0.100
#>  [45] 0.099 0.116 0.201 0.180 0.094 0.134 0.168 0.106 0.168 0.207 0.144
#>  [56] 0.094 0.203 0.141 0.070 0.065 0.146 0.142 0.154 0.118 0.078 0.125
#>  [67] 0.181 0.143 0.091 0.130 0.103 0.095 0.078 0.104 0.098 0.091 0.060
#>  [78] 0.131 0.241 0.082 0.120 0.172 0.121 0.163 0.138 0.098 0.167 0.204
#>  [89] 0.121 0.051 0.177 0.080 0.195 0.240 0.125 0.225 0.214 0.240 0.042
#> [100] 0.212
```

```
par(oma=c(0,2,0,0))
plot(nc["AREA"], col = "lightblue", graticule = TRUE,
     axes = TRUE, las = 1)
```

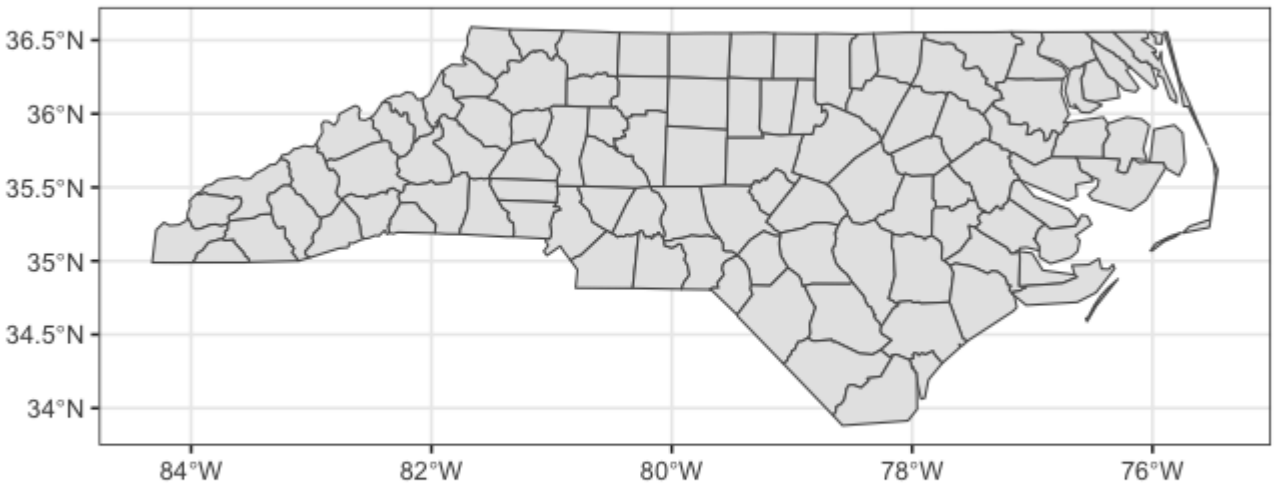


```
par(oma=c(0,2,0,0))
plot(st_geometry(nc), graticule = TRUE, axes = TRUE, las = 1)
```

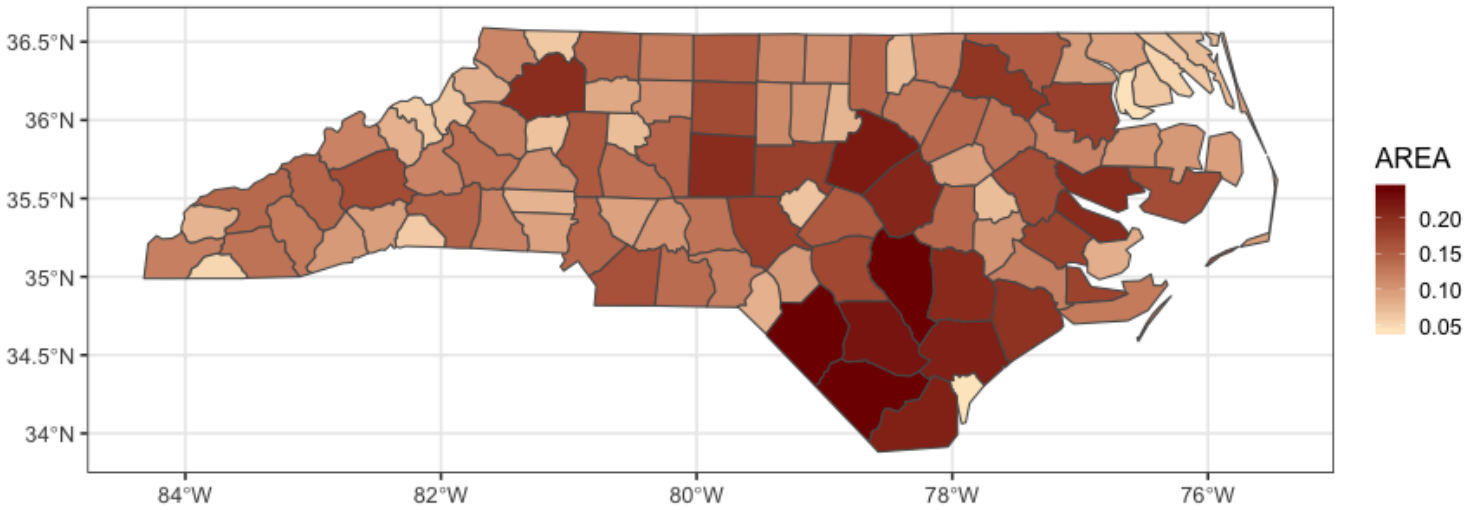


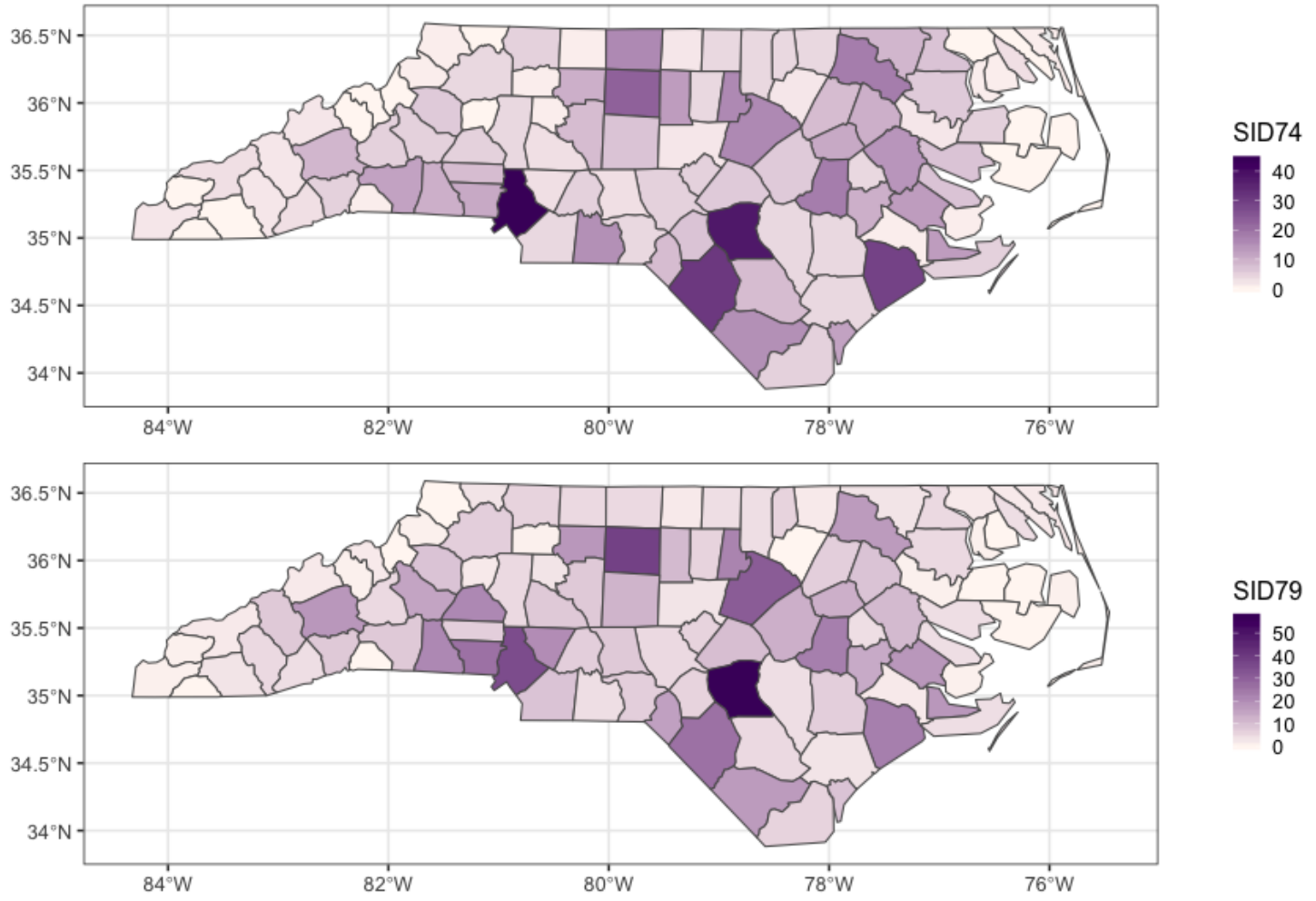
Plotting with `ggplot()`

```
ggplot(nc) +
  geom_sf() +
  theme_bw(base_size = 16)
```



```
ggplot(nc) +
  geom_sf(aes(fill = AREA)) +
  scale_fill_gradient(low = "#fee8c8", high = "#7f0000") +
  theme_bw(base_size = 16)
```

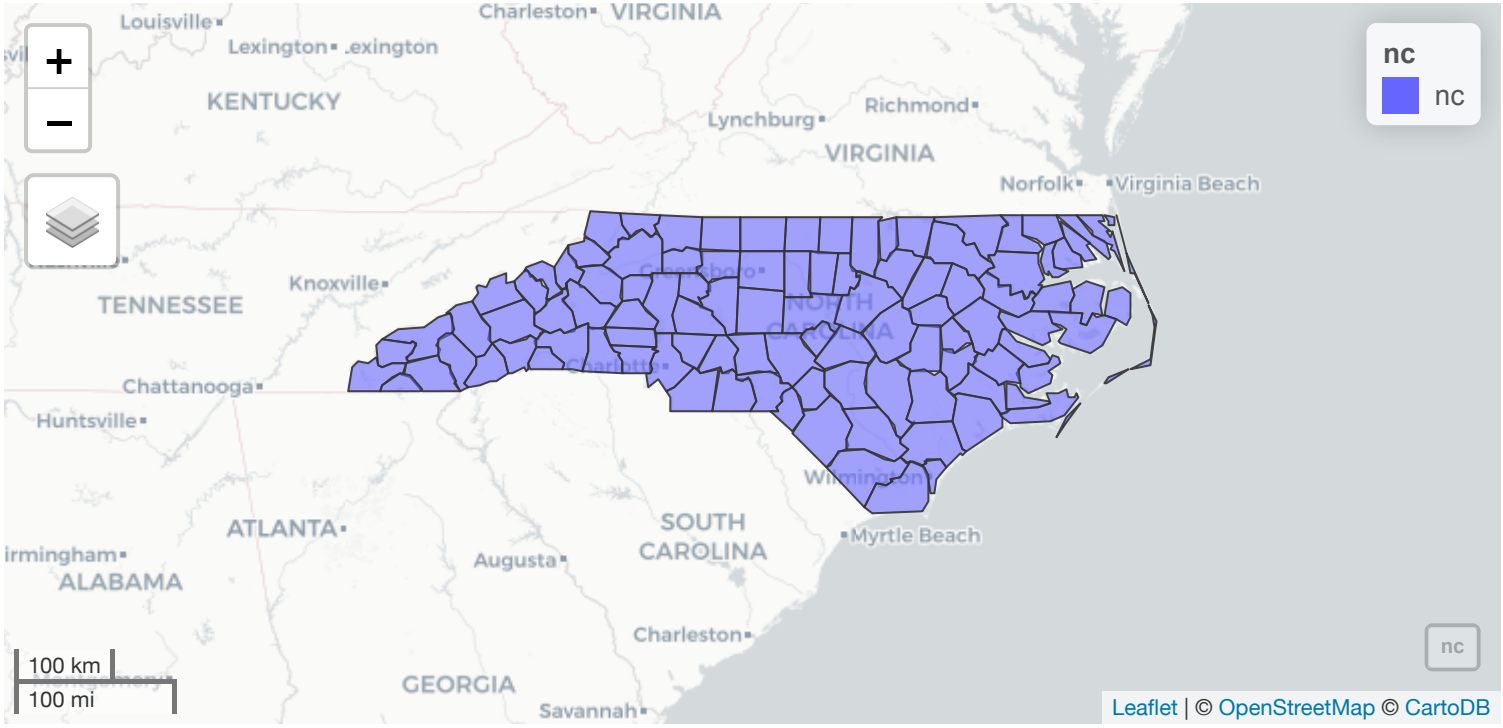



36.5°N
36°N
35.5°N
35°N
34.5°N
34°N
84°W
82°W
80°W
78°W
76°W
SID74
40
30
20
10
0
SID79
50
40
30
20
10
0

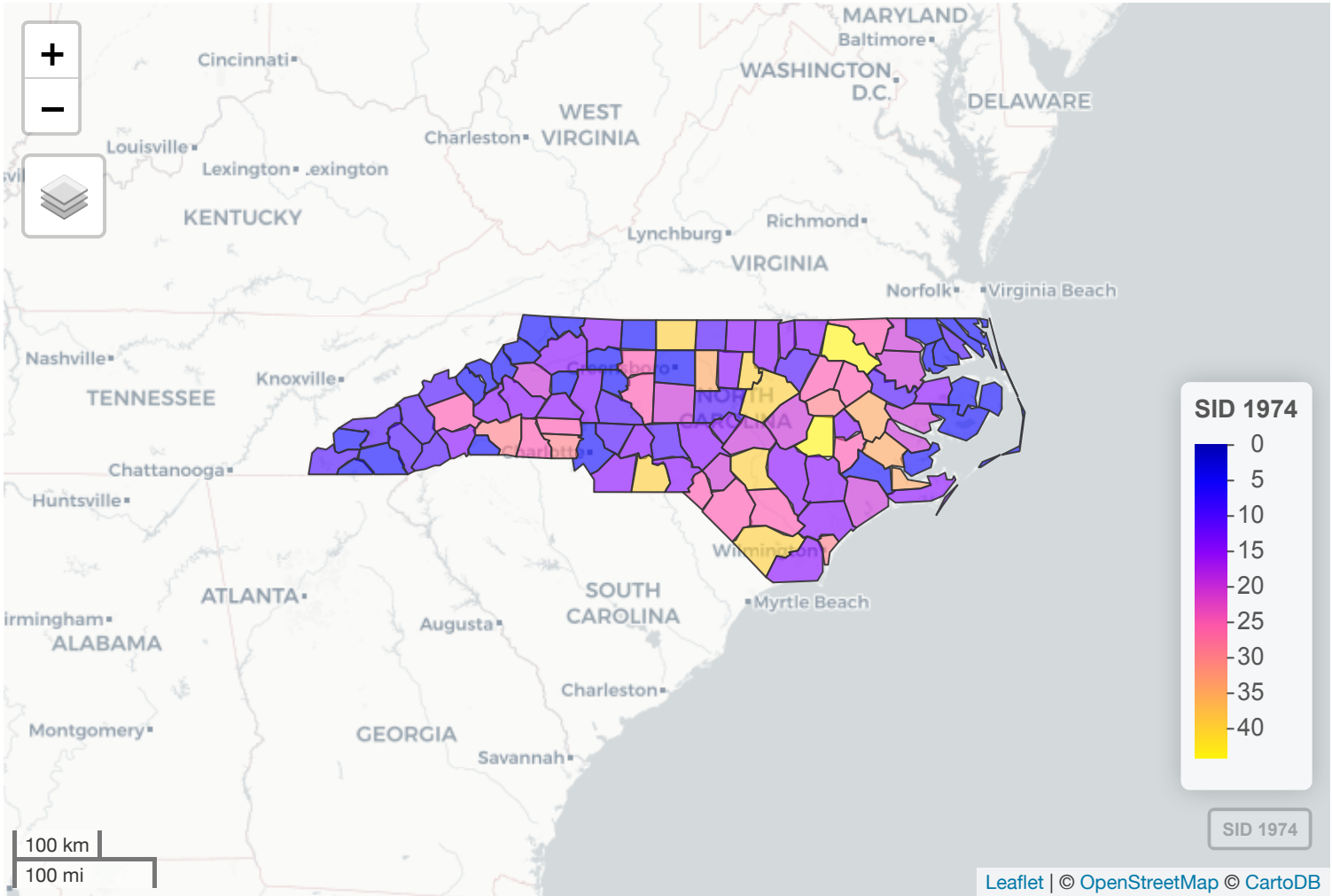
```
p1 <- ggplot(nc) +
  geom_sf(aes(fill = SID74)) +
  scale_fill_gradient(low = "#fff7f3", high = "#49006a") +
  theme_bw(base_size = 16)

p2 <- ggplot(nc) +
  geom_sf(aes(fill = SID79)) +
  scale_fill_gradient(low = "#fff7f3", high = "#49006a") +
  theme_bw(base_size = 16)

p1 / p2
```

Plotting with `mapview()`

```
mapview(nc)
```



```
mapviewOptions(legend.pos = "bottomright")
mapview(nc["SID74"], col.regions = sf.colors(10), layer.name = "SID 1974"
```



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.

https://www.nconemap.gov/datasets/e5ddff9b96204c6181be7c022e61d946_0

We can directly download and unzip the shapefile via

```
download.file("https://opendata.arcgis.com/datasets/e5ddff9b96204c6181be7
              destfile = "data/Gamelands.zip")
unzip("data/Gamelands.zip", exdir = "data/")
```

To see the available files

```
list.files(path = "data/")[1:5]
```

```
#> [1] "679190a9-3cfb-4be4-9a1e-255188fd3f6e202044-1-707iid.5jdc8.cpg"
#> [2] "679190a9-3cfb-4be4-9a1e-255188fd3f6e202044-1-707iid.5jdc8.dbf"
#> [3] "679190a9-3cfb-4be4-9a1e-255188fd3f6e202044-1-707iid.5jdc8.prj"
#> [4] "679190a9-3cfb-4be4-9a1e-255188fd3f6e202044-1-707iid.5jdc8.shp"
#> [5] "679190a9-3cfb-4be4-9a1e-255188fd3f6e202044-1-707iid.5jdc8.shx"
```

Read in the shapefile

```
nc_gamelands <- st_read("data/679190a9-3cfb-4be4-9a1e-255188fd3f6e202044-
```

```
print(nc_gamelands, n = 5)
```

```
#> Simple feature collection with 94 features and 6 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: 127456.7 ymin: 26560.42 xmax: 923523.8 ymax: 318097.4
#> epsg (SRID):    32119
#> proj4string:    +proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333333334 +lat_0=33.75 +lon_0=-79 +x_
#> First 5 features:
#>   OBJECTID          GML_HAB SUM_ACRES GameLandID Shape__Are Shape__Len
#> 1        1            Alcoa 11210.840          1   45367613  447378.38
#> 2        2 Alligator River 24439.089          2   98901485  151120.16
#> 3        3       Angola Bay 34067.381          3  137865800   87534.59
#> 4        4     Bachelor Bay  2786.258          4   11275585   26613.27
#> 5        5    Bertie County  3883.768          5   15717053   67472.65
#>                       geometry
#> 1 MULTIPOLYGON (((512096.2 18...
#> 2 MULTIPOLYGON (((869633.1 24...
#> 3 MULTIPOLYGON (((721333.1 10...
#> 4 MULTIPOLYGON (((813742.2 23...
#> 5 MULTIPOLYGON (((797133.8 24...
```

Metadata for each `sf` object

```
nc
#> Simple feature collection with 100 features and 14 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 3
#> epsg (SRID):    4267
#> proj4string:    +proj=longlat +datum=NAD27 +no_defs
#> First 10 features:
```

```
nc_gamelands
#> Simple feature collection with 94 features and 6 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: 127456.7 ymin: 26560.42 xmax: 923523.8 ymax: 318
#> epsg (SRID):    32119
#> proj4string:    +proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333
#> First 10 features:
```

Check the CRS

```
st_crs(nc)
```

```
#> Coordinate Reference System:
#>   EPSG: 4267
#>   proj4string: "+proj=longlat +datum=NAD27 +no_defs"
```

```
st_crs(nc_gamelands)
```

```
#> Coordinate Reference System:
#>   EPSG: 32119
#>   proj4string: "+proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333333334 +l
```

Coordinate reference systems (CRS)

- CRS provide a standardized way of describing locations.
- Different CRS arise from various ways data were gathered, the locations, and purposes of the data.
- A CRS is comprised of
  - an ellipsoid, to define the earth's shape;
  - a datum, to define the origin and orientation of coordinate axes;
  - a projection, to go from 3D to 2D.
- It is important that you transform your spatial data to a common CRS before plotting.

Transform CRS

```
nc_gamelands <- st_transform(nc_gamelands, st_crs(nc))
```

```
st_crs(nc)
```

```
#> Coordinate Reference System:
#>   EPSG: 4267
#>   proj4string: "+proj=longlat +datum=NAD27 +no_defs"
```

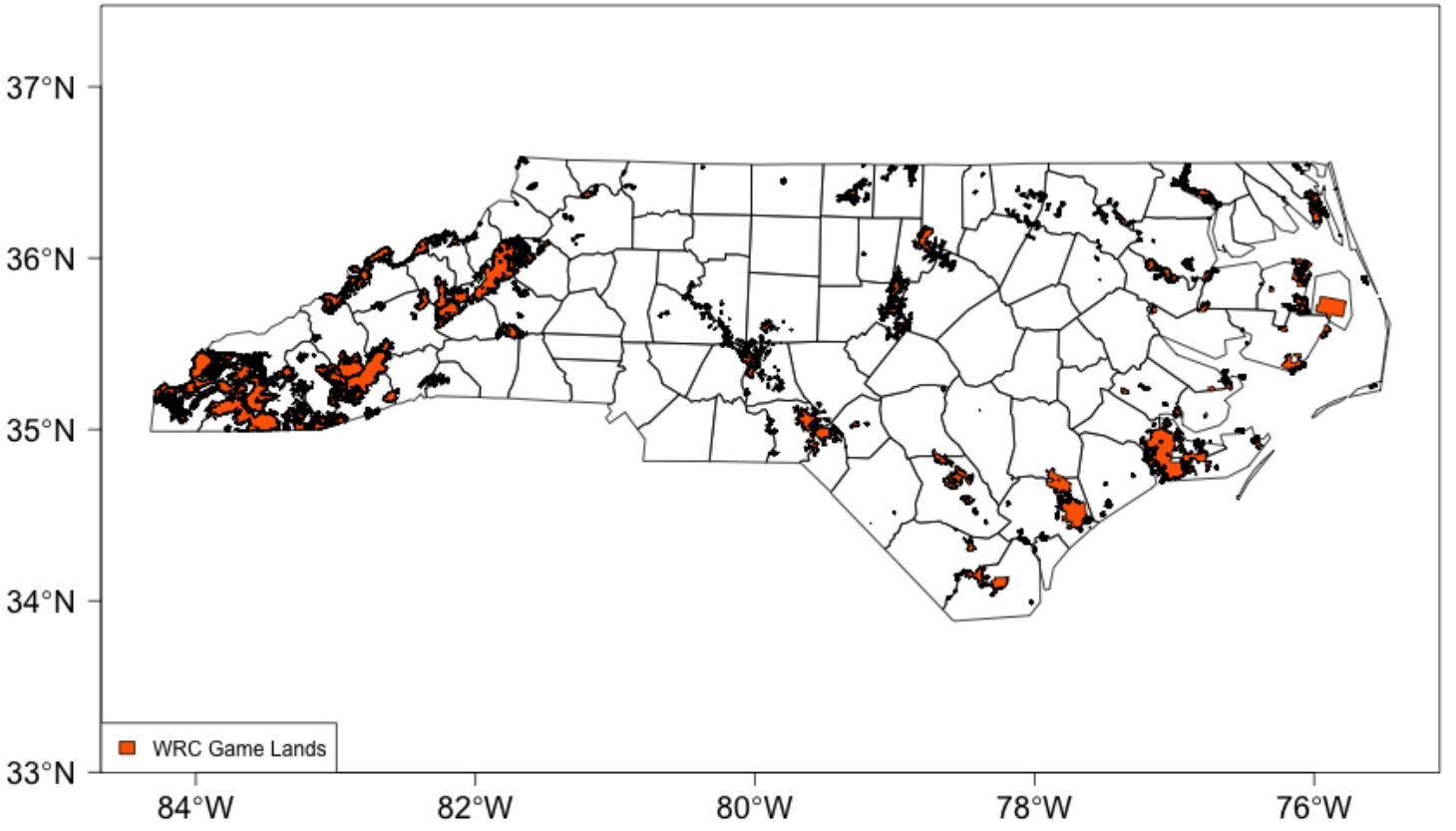
```
st_crs(nc_gamelands)
```

```
#> Coordinate Reference System:
#>   EPSG: 4267
#>   proj4string: "+proj=longlat +datum=NAD27 +no_defs"
```

Map overlay with `plot()`

```
plot(st_geometry(nc), axes = T, las = 1, main = "NC Public Game Lands",
     cex.main = 3, cex.lab = 2, cex.axis = 1.5)

plot(st_geometry(nc_gamelands),
     add = T,
     col = "#ff6700")

legend("bottomleft", legend = "WRC Game Lands", fill = "#ff6700")
```

NC Public Game Lands



Map overlay with `mapview()`

```
nc_mapview <- mapview(nc, alpha.regions = .2, alpha = .9,
                  label = nc[, "NAME", drop = T],
                  layer.name = "NC Counties")
```

```
nc_gamelands_mapview <- mapview(nc_gamelands, col.regions = "#ff6700",
        label = round(nc_gamelands[, "SUM_ACRES", drop = T], 2),
        layer.name = "NC Gamelands")
```

```
nc_mapview + nc_gamelands_mapview
```

These should run in RStudio. There is an issue embedding this overlay in the slides.

Exercise

Create a map that includes NC county boundaries, Game Lands, and hazardous waste sites. Data for the hazardous waste sites is available at https://www.nconemap.gov/datasets/hazardous-waste-sites

This data set represents the location of sites within North Carolina that are regulated by the hazardous waste portions of the Resource Conservation and Recovery Act (RCRA).

Manipulating `sf` type objects

Intersects

```
nc <- st_transform(nc, st_crs(32119))
nc_gamelands <- st_transform(nc_gamelands, st_crs(32119))
```

Source: https://spatialreference.org/ref/epsg/32119/

```
durham_county <- nc %>%
  filter(NAME == "Durham")
nc[durham_county, ]
```

```
#> Simple feature collection with 6 features and 14 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: 559228.2 ymin: 195318.3 xmax: 676964.2 ymax: 310228.5
#> epsg (SRID):    32119
#> proj4string:    +proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333333334 +lat_0=33.75 +lon_0=-79 +x_
#>     AREA PERIMETER CNTY_ CNTY_ID      NAME  FIPS FIPSNO CRESS_ID BIR74
#> 13 0.143     1.663  1840    1840 Granville 37077  37077       39  1671
#> 14 0.109     1.325  1841    1841    Person 37145  37145       73  1556
#> 29 0.104     1.294  1907    1907    Orange 37135  37135       68  3164
#> 30 0.077     1.271  1908    1908    Durham 37063  37063       32  7970
#> 37 0.219     2.130  1938    1938      Wake 37183  37183       92 14484
#> 48 0.180     2.142  1973    1973   Chatham 37037  37037       19  1646
#>    SID74 NWBIR74 BIR79 SID79 NWBIR79                       geometry
#> 13     4     930  2074     4    1058 MULTIPOLYGON (((632202.4 25...
#> 14     4     613  1790     4     650 MULTIPOLYGON (((626970 2753...
#> 29     4     776  4478     6    1086 MULTIPOLYGON (((607963.3 23...
#> 30    16    3732 10432    22    4948 MULTIPOLYGON (((607963.3 23...
#> 37    16    4397 20857    31    6221 MULTIPOLYGON (((616754.3 20...
#> 48     2     591  2398     3     687 MULTIPOLYGON (((559228.2 19...
```

```
st_intersects(nc, durham_county, sparse = F) %>%
  nc[., ]
```

```
#> Simple feature collection with 6 features and 14 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: 559228.2 ymin: 195318.3 xmax: 676964.2 ymax: 310228.5
#> epsg (SRID):    32119
#> proj4string:    +proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333333334 +lat_0=33.75 +lon_0=-79 +x_
#>     AREA PERIMETER CNTY_ CNTY_ID      NAME  FIPS FIPSNO CRESS_ID BIR74
#> 13 0.143     1.663  1840    1840 Granville 37077  37077       39  1671
#> 14 0.109     1.325  1841    1841    Person 37145  37145       73  1556
#> 29 0.104     1.294  1907    1907    Orange 37135  37135       68  3164
#> 30 0.077     1.271  1908    1908    Durham 37063  37063       32  7970
#> 37 0.219     2.130  1938    1938      Wake 37183  37183       92 14484
#> 48 0.180     2.142  1973    1973   Chatham 37037  37037       19  1646
#>    SID74 NWBIR74 BIR79 SID79 NWBIR79                       geometry
#> 13     4     930  2074     4    1058 MULTIPOLYGON (((632202.4 25...
#> 14     4     613  1790     4     650 MULTIPOLYGON (((626970 2753...
#> 29     4     776  4478     6    1086 MULTIPOLYGON (((607963.3 23...
#> 30    16    3732 10432    22    4948 MULTIPOLYGON (((607963.3 23...
#> 37    16    4397 20857    31    6221 MULTIPOLYGON (((616754.3 20...
#> 48     2     591  2398     3     687 MULTIPOLYGON (((559228.2 19...
```

Touches

```
st_touches(nc, durham_county, sparse = F) %>%
  nc[., ]
```

```
#> Simple feature collection with 5 features and 14 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: 559228.2 ymin: 195318.3 xmax: 676964.2 ymax: 310228.5
#> epsg (SRID):    32119
#> proj4string:    +proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333333334 +l
#>     AREA PERIMETER CNTY_ CNTY_ID      NAME  FIPS FIPSNO CRESS_ID BIR74
#> 13 0.143     1.663  1840    1840 Granville 37077  37077       39  1671
#> 14 0.109     1.325  1841    1841    Person 37145  37145       73  1556
#> 29 0.104     1.294  1907    1907    Orange 37135  37135       68  3164
#> 37 0.219     2.130  1938    1938      Wake 37183  37183       92 14484
#> 48 0.180     2.142  1973    1973   Chatham 37037  37037       19  1646
#>    SID74 NWBIR74 BIR79 SID79 NWBIR79                       geometry
#> 13     4     930  2074     4    1058 MULTIPOLYGON (((632202.4 25...
#> 14     4     613  1790     4     650 MULTIPOLYGON (((626970 2753...
#> 29     4     776  4478     6    1086 MULTIPOLYGON (((607963.3 23...
#> 37    16    4397 20857    31    6221 MULTIPOLYGON (((616754.3 20...
#> 48     2     591  2398     3     687 MULTIPOLYGON (((559228.2 19...
```

Join

```
durham_area_counties <- st_intersects(nc, durham_county, sparse = F) %>%
  nc[., ]

durham_area_gamelands <- st_join(durham_area_counties,
                                 nc_gamelands, join = st_intersects)
```

```
print(durham_area_gamelands, n = 3)
```

```
#> Simple feature collection with 14 features and 20 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: 559228.2 ymin: 195318.3 xmax: 676964.2 ymax: 310228.5
#> epsg (SRID):    32119
#> proj4string:    +proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333333334 +lat_0=33.75 +lon_0=-79 +x_
#> First 3 features:
#>       AREA PERIMETER CNTY_ CNTY_ID      NAME  FIPS FIPSNO CRESS_ID BIR74
#> 13   0.143     1.663  1840    1840 Granville 37077  37077       39  1671
#> 14   0.109     1.325  1841    1841    Person 37145  37145       73  1556
#> 14.1 0.109     1.325  1841    1841    Person 37145  37145       73  1556
#>      SID74 NWBIR74 BIR79 SID79 NWBIR79 OBJECTID               GML_HAB
#> 13       4     930  2074     4    1058       12 Butner-Falls of Neuse
#> 14       4     613  1790     4     650       37                  Hyco
#> 14.1     4     613  1790     4     650       49                  Mayo
#>      SUM_ACRES GameLandID Shape__Are Shape__Len
#> 13   40674.205         13  164602670  421442.14
#> 14    3979.375         38   16103959   62956.92
#> 14.1  5247.622         46   21236373  124167.24
#>                           geometry
#> 13   MULTIPOLYGON (((632202.4 25...
#> 14   MULTIPOLYGON (((626970 2753...
#> 14.1 MULTIPOLYGON (((626970 2753...
```

Proximity

```
st_is_within_distance(durham_county, nc, dist = 17550, sparse = F) %>%
  nc[., ]
```

```
#> Simple feature collection with 7 features and 14 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: 559228.2 ymin: 195318.3 xmax: 698975.2 ymax: 310228.5
#> epsg (SRID):    32119
#> proj4string:    +proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333333334 +lat_0=33.75 +lon_0=-79 +x_
#>     AREA PERIMETER CNTY_ CNTY_ID      NAME  FIPS FIPSNO CRESS_ID BIR74
#> 13 0.143     1.663  1840    1840 Granville 37077  37077       39  1671
#> 14 0.109     1.325  1841    1841    Person 37145  37145       73  1556
#> 24 0.128     1.554  1897    1897  Franklin 37069  37069       35  1399
#> 29 0.104     1.294  1907    1907    Orange 37135  37135       68  3164
#> 30 0.077     1.271  1908    1908    Durham 37063  37063       32  7970
#> 37 0.219     2.130  1938    1938      Wake 37183  37183       92 14484
#> 48 0.180     2.142  1973    1973   Chatham 37037  37037       19  1646
#>    SID74 NWBIR74 BIR79 SID79 NWBIR79                       geometry
#> 13     4     930  2074     4    1058 MULTIPOLYGON (((632202.4 25...
#> 14     4     613  1790     4     650 MULTIPOLYGON (((626970 2753...
#> 24     2     736  1863     0     950 MULTIPOLYGON (((676964.2 22...
#> 29     4     776  4478     6    1086 MULTIPOLYGON (((607963.3 23...
#> 30    16    3732 10432    22    4948 MULTIPOLYGON (((607963.3 23...
#> 37    16    4397 20857    31    6221 MULTIPOLYGON (((616754.3 20...
#> 48     2     591  2398     3     687 MULTIPOLYGON (((559228.2 19...
```

```
st_overlaps(nc, nc_gamelands[nc_gamelands$GML_HAB == "Jordan", ], sparse = F) %>%
  nc[., ]
```

```
#> Simple feature collection with 4 features and 14 fields
#> geometry type:  MULTIPOLYGON
#> dimension:      XY
#> bbox:           xmin: 559228.2 ymin: 195318.3 xmax: 676964.2 ymax: 275782.8
#> epsg (SRID):    32119
#> proj4string:    +proj=lcc +lat_1=36.16666666666666 +lat_2=34.33333333333334 +lat_0=33.75 +lon_0=-79 +x_
#>     AREA PERIMETER CNTY_ CNTY_ID    NAME  FIPS FIPSNO CRESS_ID BIR74 SID74
#> 29 0.104     1.294  1907    1907  Orange 37135  37135       68  3164     4
#> 30 0.077     1.271  1908    1908  Durham 37063  37063       32  7970    16
#> 37 0.219     2.130  1938    1938    Wake 37183  37183       92 14484    16
#> 48 0.180     2.142  1973    1973 Chatham 37037  37037       19  1646     2
#>    NWBIR74 BIR79 SID79 NWBIR79                       geometry
#> 29     776  4478     6    1086 MULTIPOLYGON (((607963.3 23...
#> 30    3732 10432    22    4948 MULTIPOLYGON (((607963.3 23...
#> 37    4397 20857    31    6221 MULTIPOLYGON (((616754.3 20...
#> 48     591  2398     3     687 MULTIPOLYGON (((559228.2 19...
```

For more geometry predicates see Simple Features Cheatsheet

Exercise

Create a plot of North Carolina's Game Lands and all the waste sites within 100 meters of a Game Land area. Try two of the three plot functions.

References

- Simple Features for R vignette, https://r-spatial.github.io/sf/
- `mapview` vignette, https://r-spatial.github.io/mapview/index.html
- Coordinate Reference Systems in R
  https://www.nceas.ucsb.edu/~frazier/RSpatialGuides/OverviewCoordinateReferenceSystems.pdf
  by Melanie Frazier