Lecture 17

Spatial Data and Cartography (Part 2)

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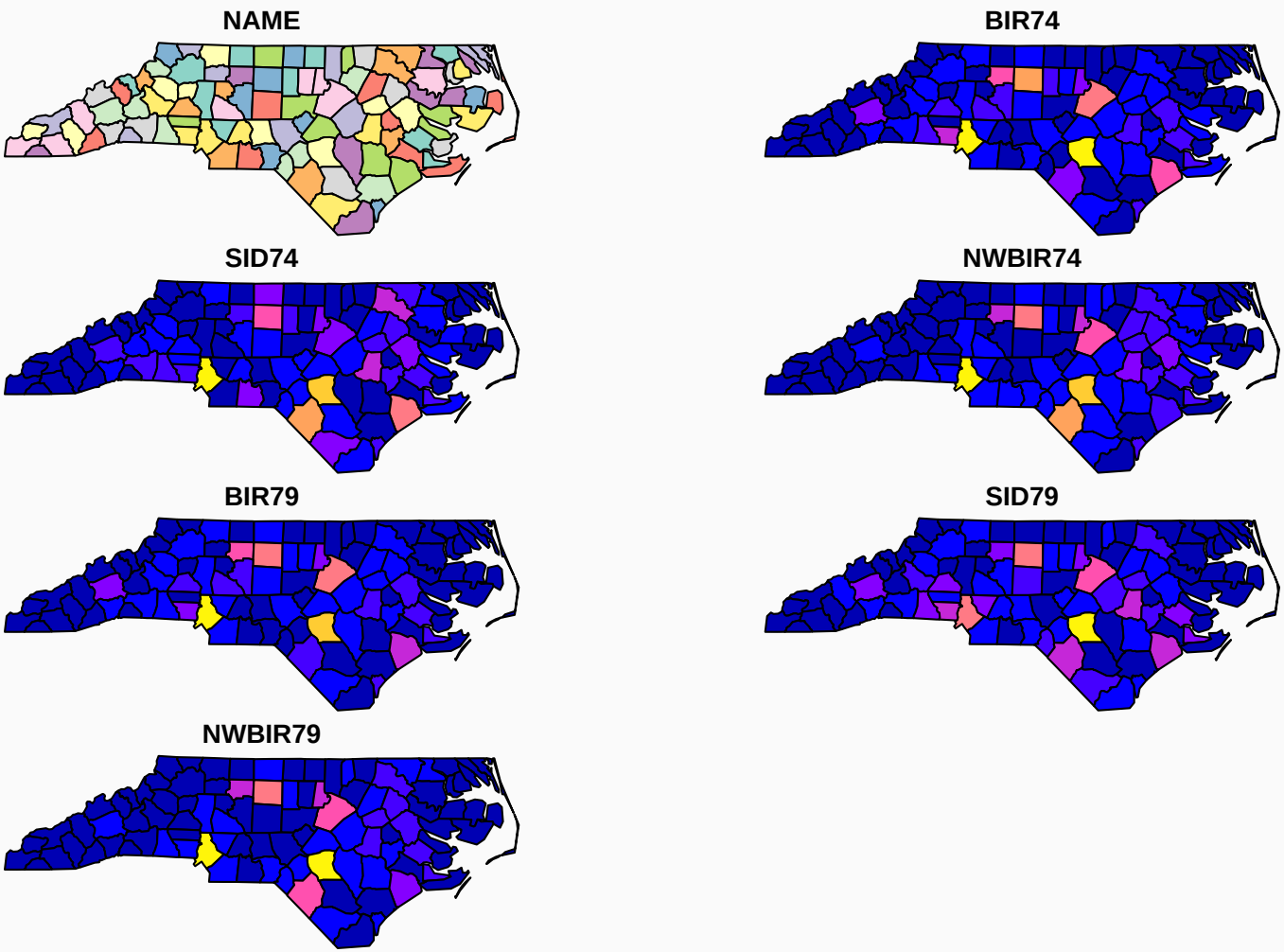
Plotting

Example Data - NC SIDS

```
nc = st_read(system.file("shape/nc.shp", package="sf"), quiet = TRUE) %>%
  select(-(AREA:CNTY_ID), -(FIPS:CRESS_ID))

head(nc, n = 10)
## Simple feature collection with 10 features and 7 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -81.74107 ymin: 36.07282 xmax: -75.77316 ymax: 36.58965
## epsg (SRID):    4267
## proj4string:    +proj=longlat +datum=NAD27 +no_defs
##            NAME BIR74 SID74 NWBIR74 BIR79 SID79 NWBIR79
## 1          Ashe  1091     1      10  1364     0      19
## 2     Alleghany   487     0      10   542     3      12
## 3         Surry  3188     5     208  3616     6     260
## 4     Currituck   508     1     123   830     2     145
## 5  Northampton  1421     9    1066  1606     3    1197
## 6      Hertford  1452     7     954  1838     5    1237
## 7        Camden   286     0     115   350     2     139
## 8         Gates   420     0     254   594     2     371
## 9        Warren   968     4     748  1190     2     844
## 10       Stokes  1612     1     160  2038     5     176
##                            geometry
## 1  MULTIPOLYGON(((-81.47275543...
## 2  MULTIPOLYGON(((-81.23989105...
## 3  MULTIPOLYGON(((-80.45634460...
## 4  MULTIPOLYGON(((-76.00897216...
## 5  MULTIPOLYGON(((-77.21766662...
```

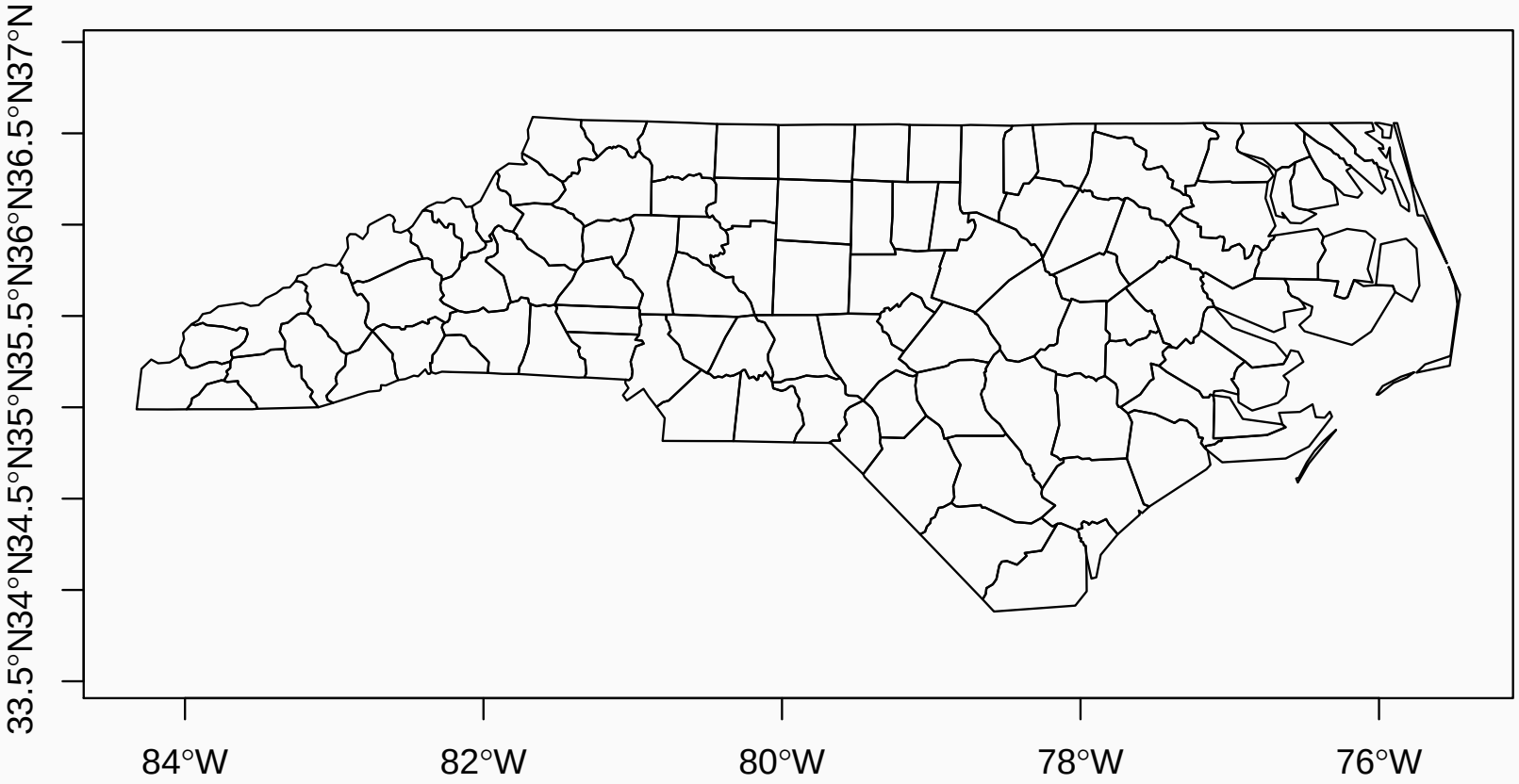
Base Plots

```
plot(nc)
```



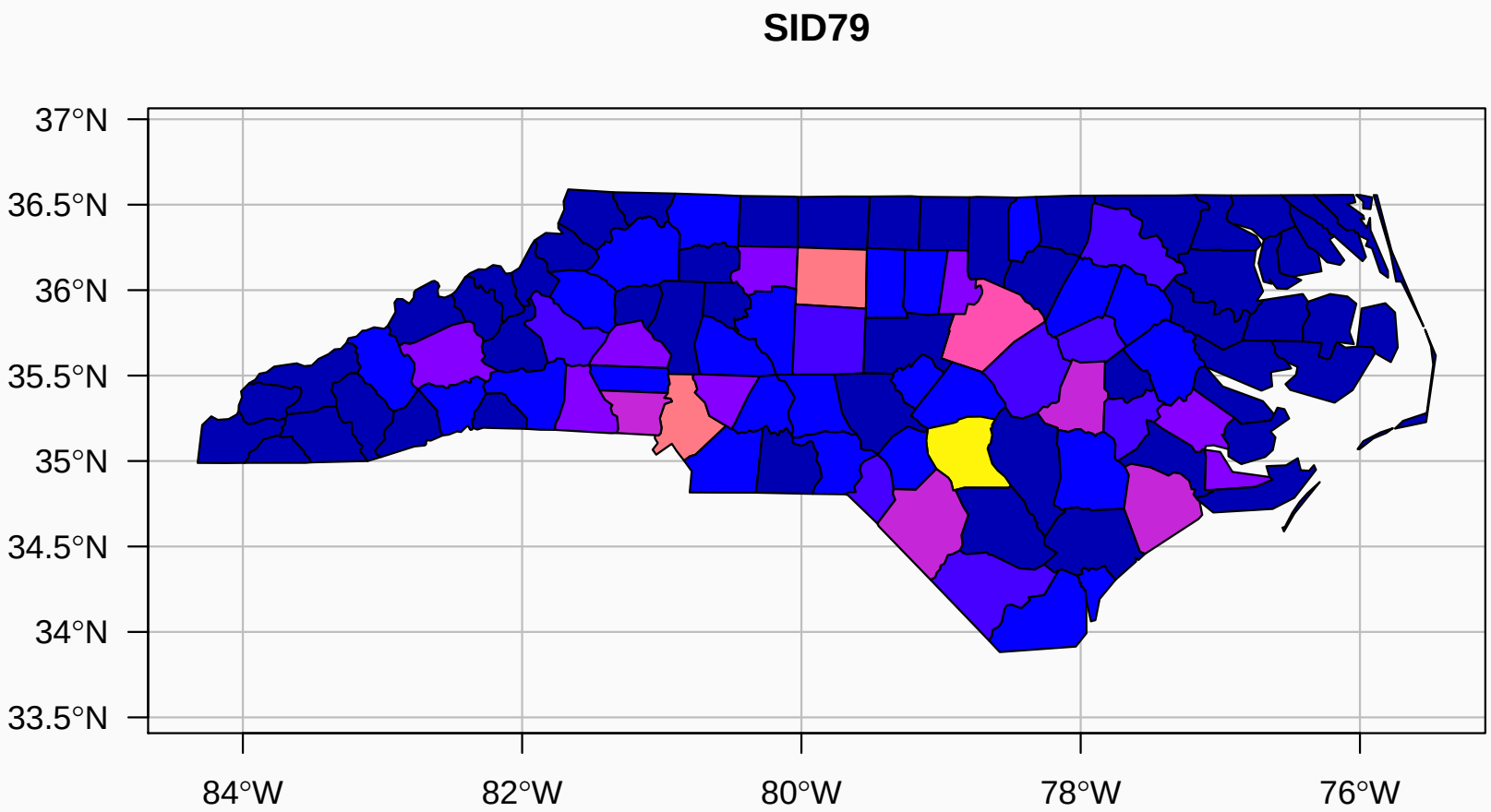
Geometry Plot

```
plot(st_geometry(nc), axes=TRUE)
```



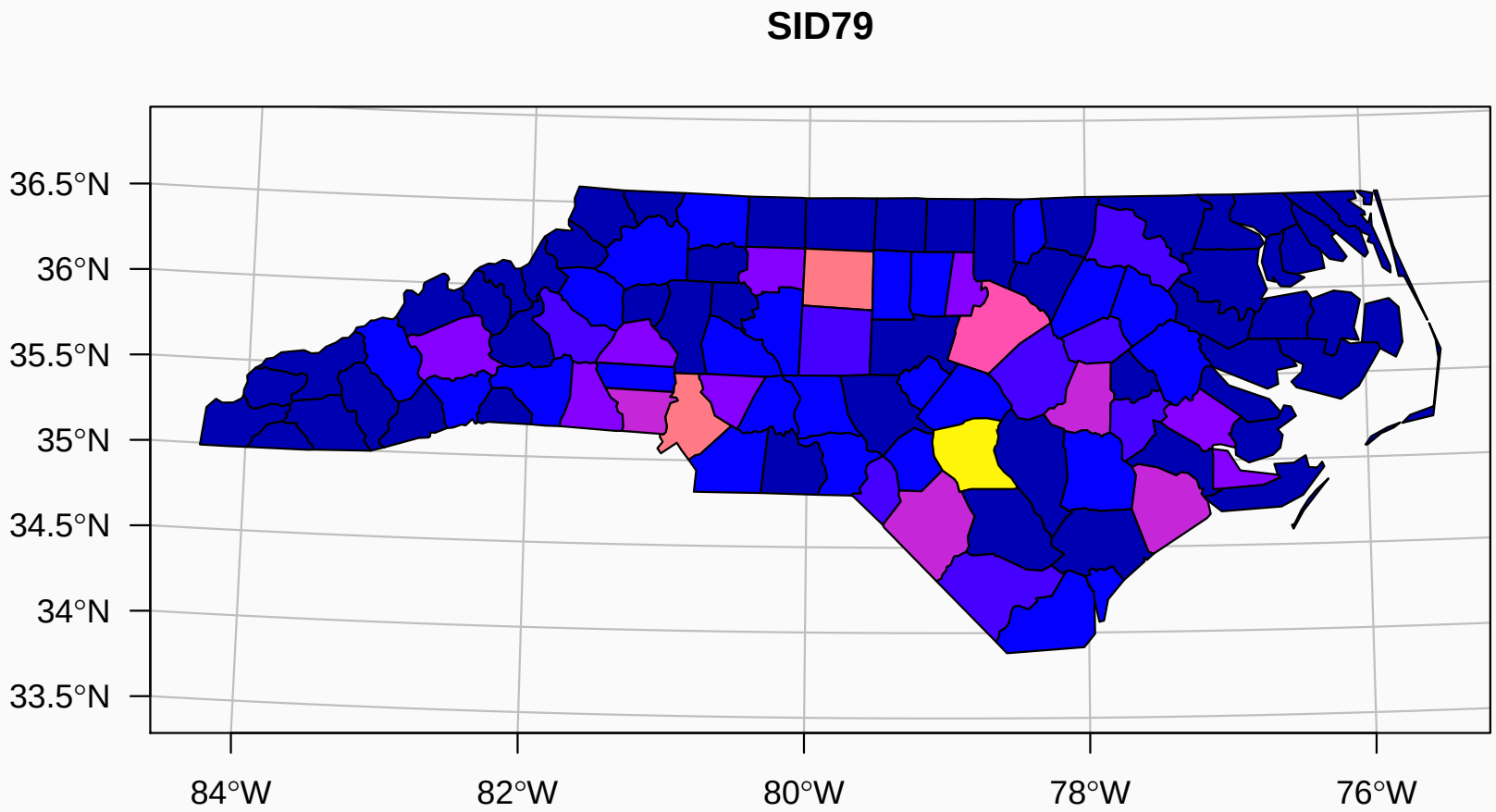
Graticules

```
plot(nc[,"SID79"], graticule=st_crs(nc), axes=TRUE, las=1)
```



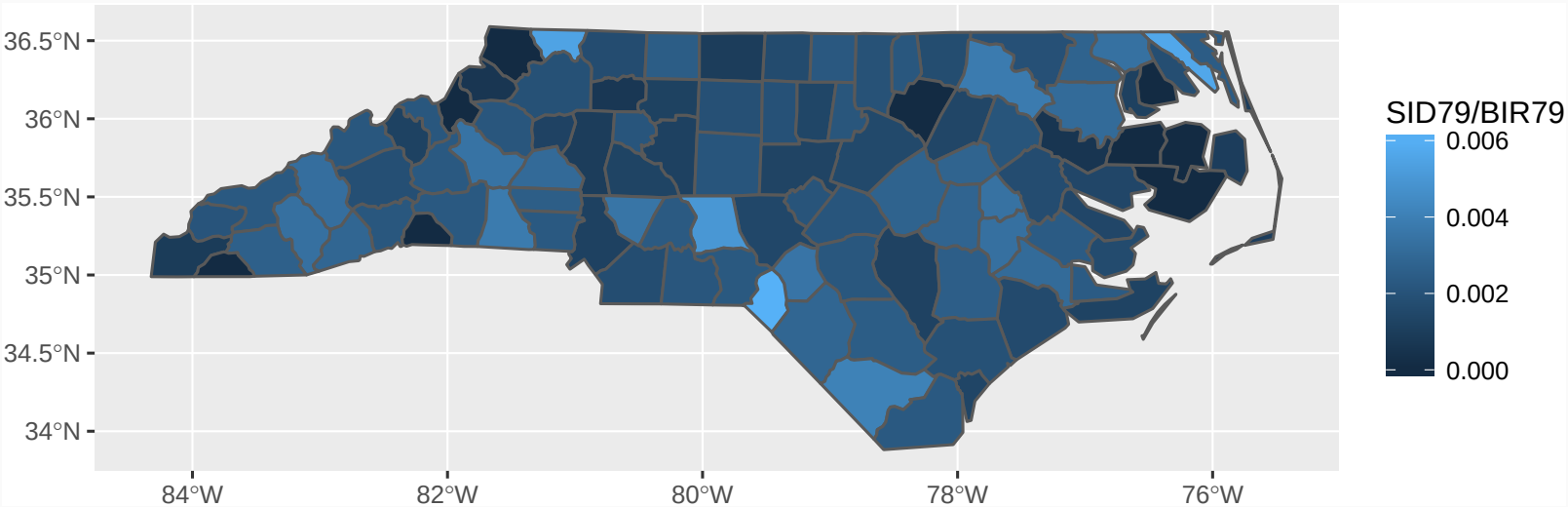
Graticules (EPSG:3631)

```
plot(st_transform(nc[,"SID79"], 3631), graticule=st_crs(nc), axes=TRUE, las=1)
```



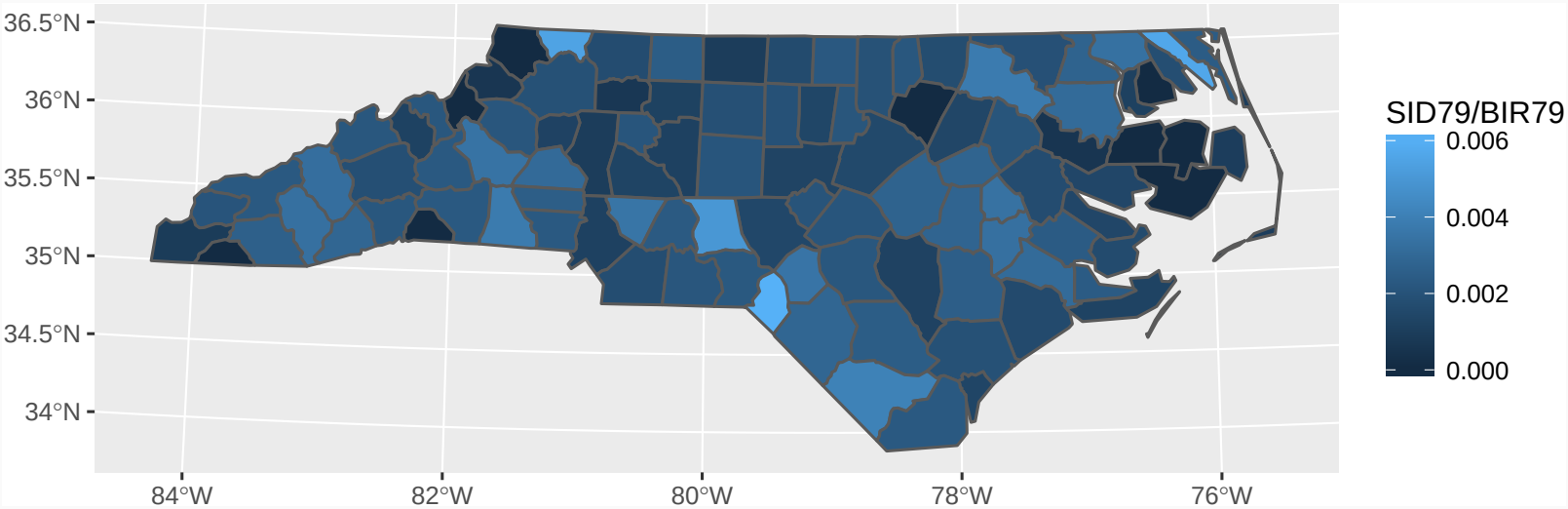
ggplot2 2.2.1.9 (dev)

```
ggplot(nc) +
  geom_sf(aes(fill=SID79 / BIR79))
```



ggplot2 + projections

```
ggplot(st_transform(nc, 3631)) +
  geom_sf(aes(fill=SID79 / BIR79))
```

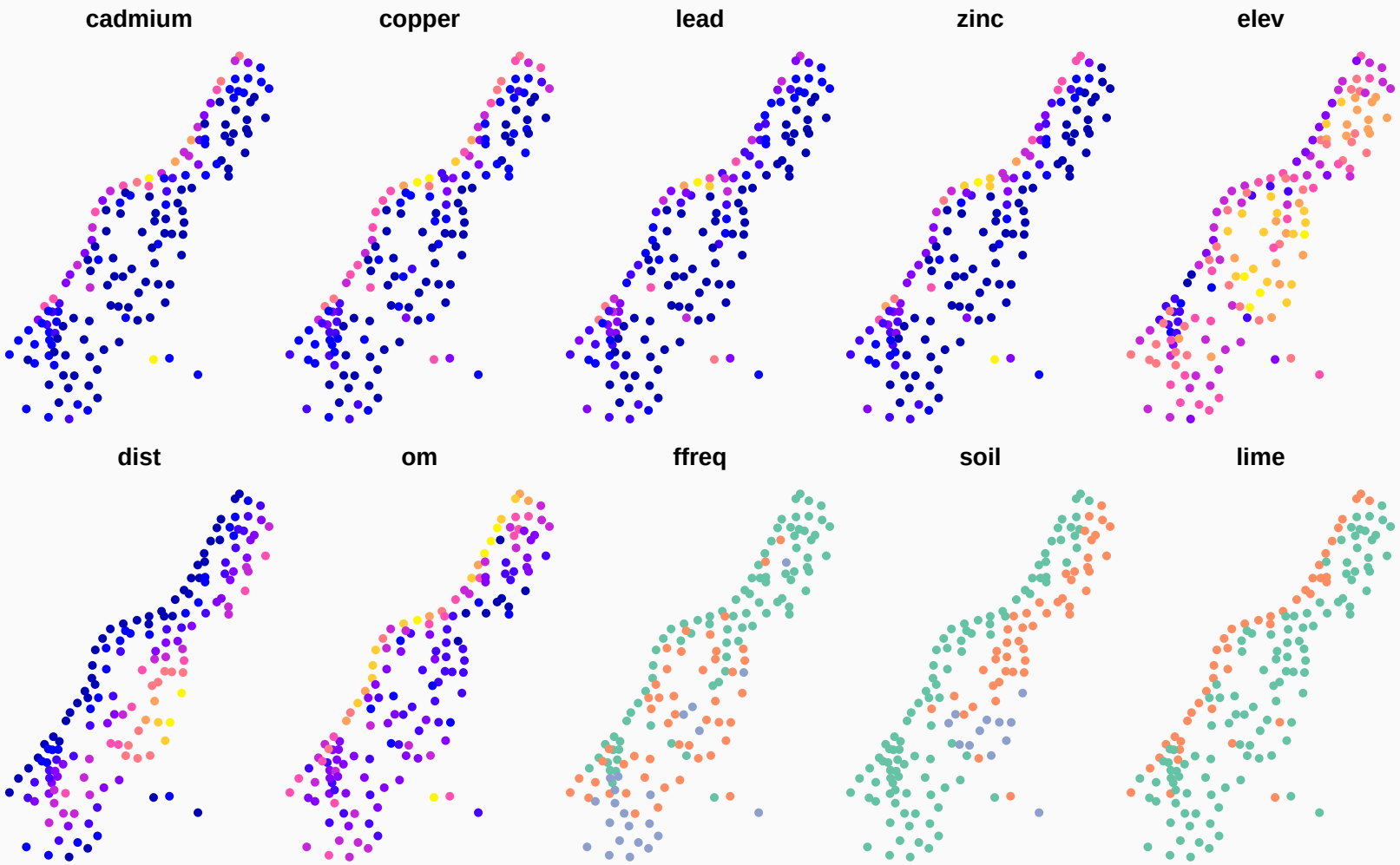


Example Data - Meuse

```
data(meuse, meuse.riv, package="sp")

meuse = st_as_sf(meuse, coords=c("x", "y"), crs=28992)
meuse_riv = st_polygon(list(meuse.riv)) %>% st_sfc() %>% st_set_crs(28992)

meuse
## Simple feature collection with 155 features and 12 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: 178605 ymin: 329714 xmax: 181390 ymax: 333611
## epsg (SRID):    28992
## proj4string:    +proj=sterea +lat_0=52.15616055555555 +lon_0=5.38763888888889 +k=0.
## First 20 features:
##    cadmium copper lead zinc  elev       dist   om ffreq soil lime
## 1     11.7     85  299 1022 7.909 0.00135803 13.6     1    1    1
## 2      8.6     81  277 1141 6.983 0.01222430 14.0     1    1    1
## 3      6.5     68  199  640 7.800 0.10302900 13.0     1    1    1
## 4      2.6     81  116  257 7.655 0.19009400  8.0     1    2    0
## 5      2.8     48  117  269 7.480 0.27709000  8.7     1    2    0
## 6      3.0     61  137  281 7.791 0.36406700  7.8     1    2    0
## 7      3.2     31  132  346 8.217 0.19009400  9.2     1    2    0
## 8      2.8     29  150  406 8.490 0.09215160  9.5     1    1    0
## 9      2.4     37  133  347 8.668 0.18461400 10.6     1    1    0
## 10     1.6     24   80  183 9.049 0.30970200  6.3     1    2    0
## 11     1.4     25   86  189 9.015 0.31511600  6.4     1    2    0
## 12     1.8     25   97  251 9.073 0.22812300  9.0     1    1    0
## 13    11.2     93  285 1096 7.320 0.00000000 15.4     1    1    1
## 14     2.5     31  183  504 8.815 0.11393200  8.4     1    1    0
```

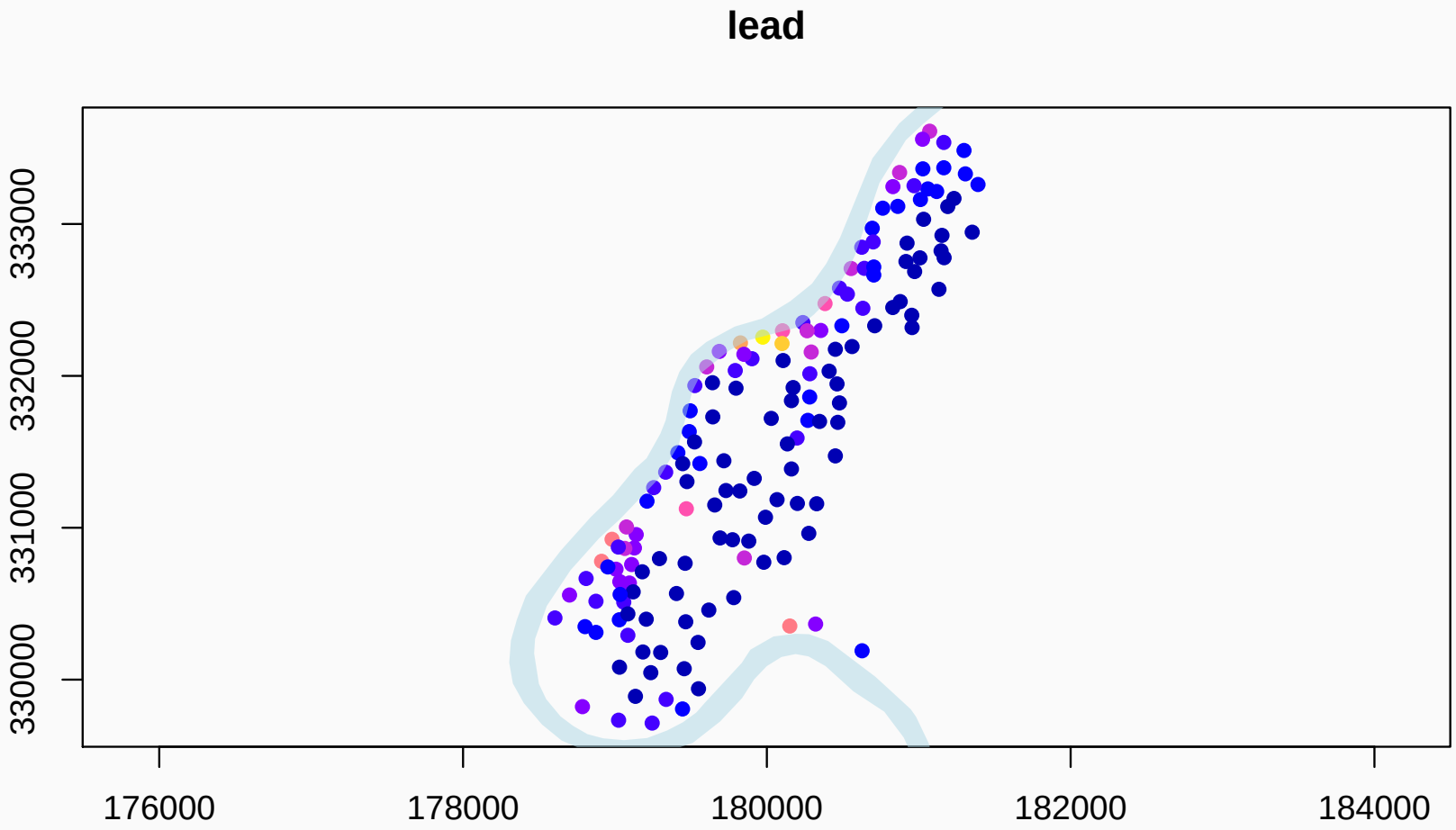
Meuse

```
plot(meuse, pch=16)
```



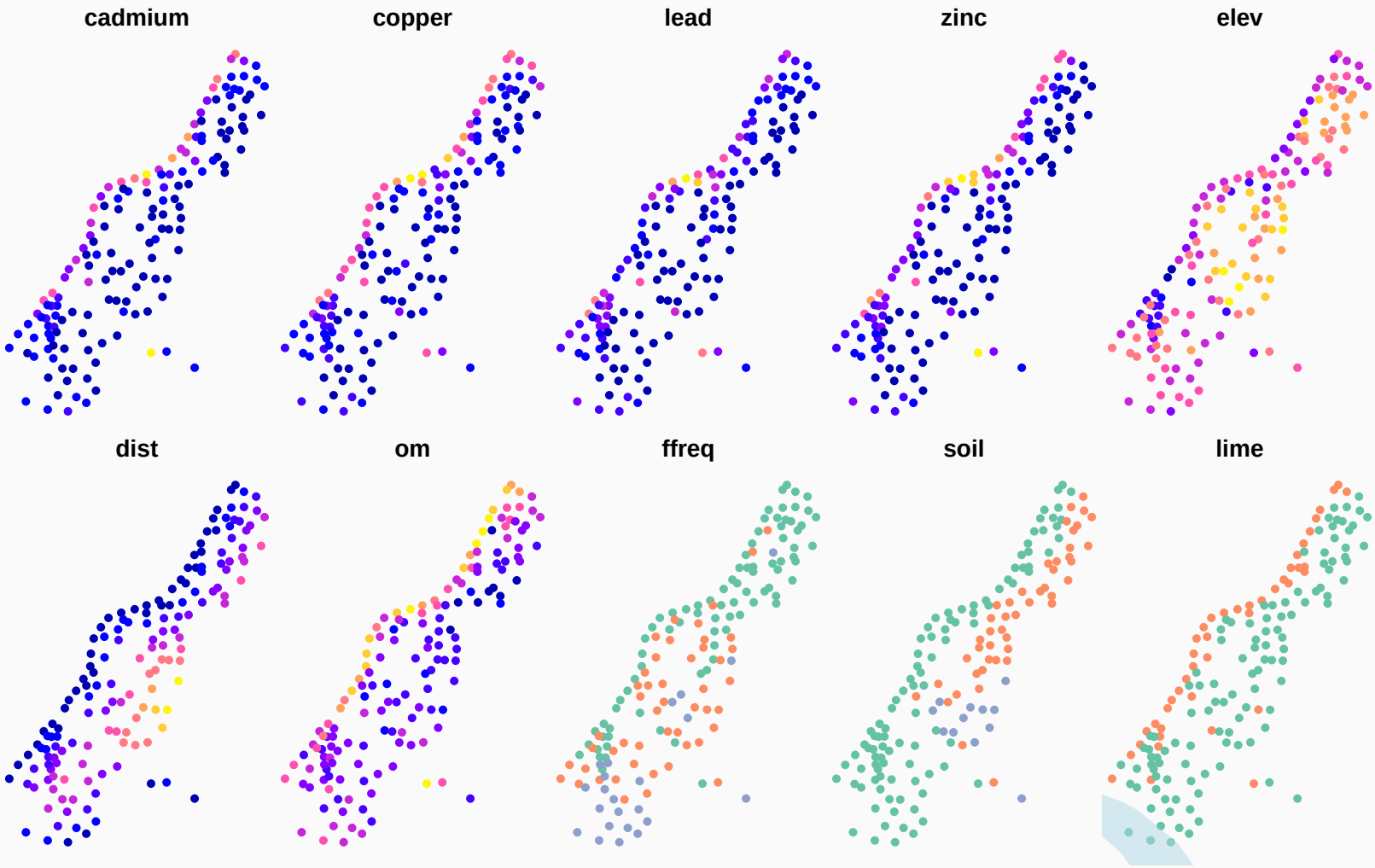
Layering plots

```
plot(meuse[,"lead"], pch=16, axes=TRUE)
plot(meuse_riv, col=adjustcolor("lightblue", alpha.f=0.5), add=TRUE, border = NA)
```



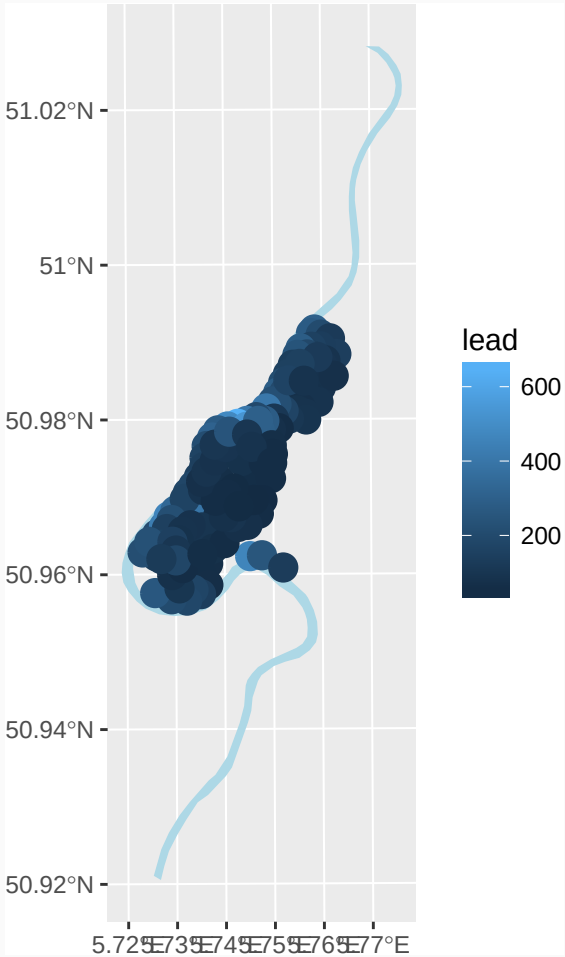
Layering plots (oops)

```
plot(meuse, pch=16)
plot(meuse_riv, col=adjustcolor("lightblue", alpha.f=0.5), add=TRUE, border = NA)
```



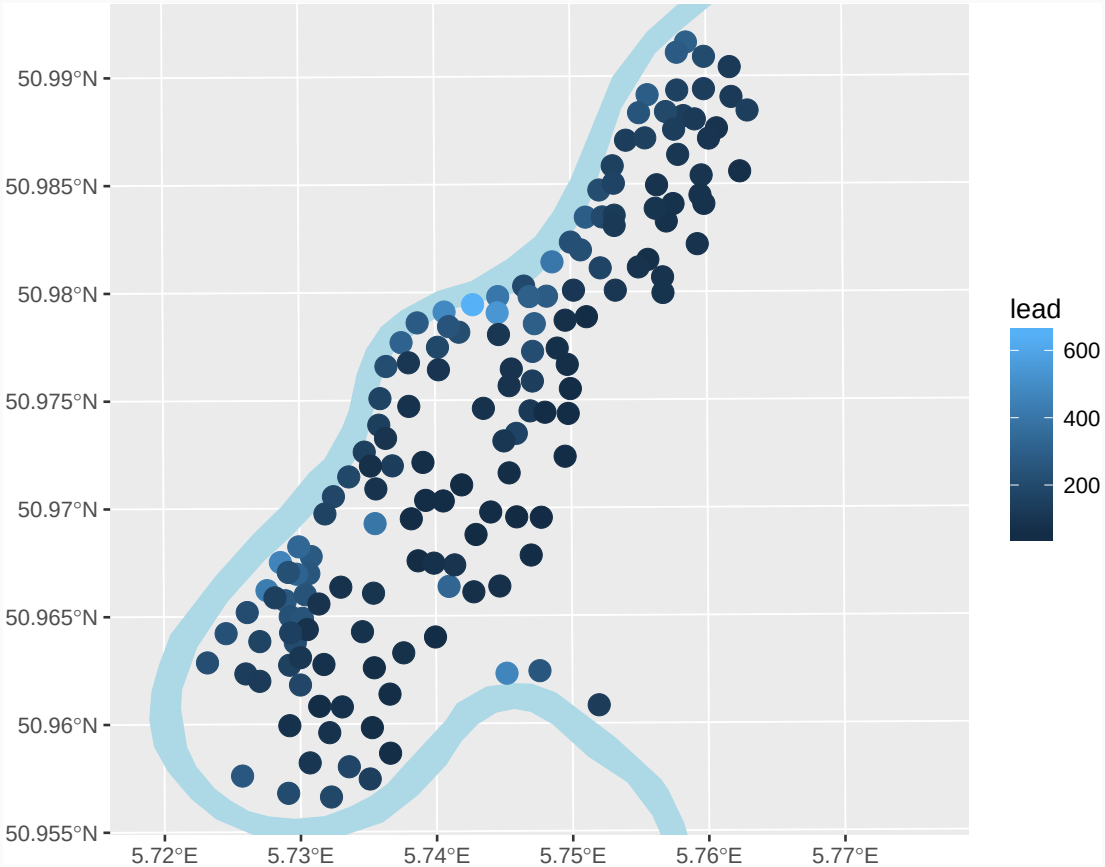
ggplot2

```
ggplot() +
  geom_sf(data=st_sf(meuse_riv), fill="lightblue", color=NA) +
  geom_sf(data=meuse, aes(color=lead), size=1)
```



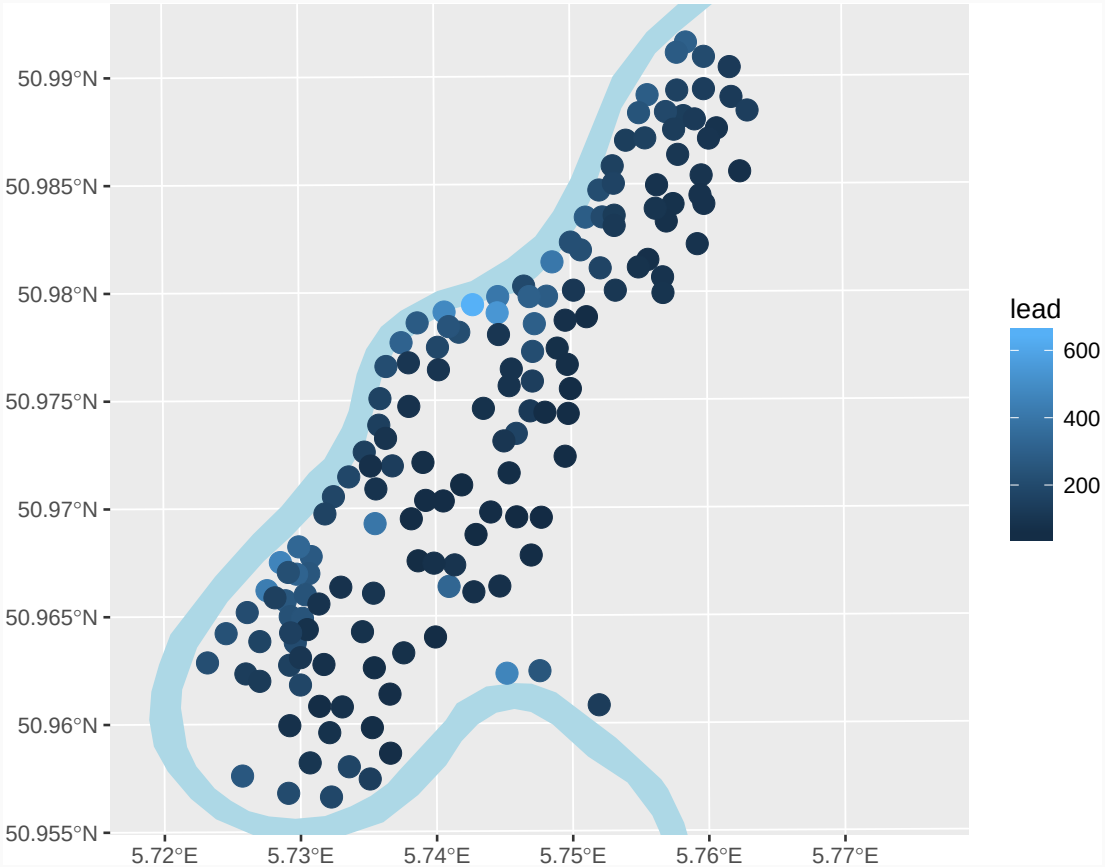
ggplot2 - axis limits

```
ggplot() +
  geom_sf(data=st_sf(meuse_riv), fill="lightblue", color=NA) +
  geom_sf(data=meuse, aes(color=lead), size=0.1) +
  ylim(329714, 333611)
```



ggplot2 - bounding box

```
ggplot() +
  geom_sf(data=st_sf(meuse_riv), fill="lightblue", color=NA) +
  geom_sf(data=meuse, aes(color=lead), size=0.1) +
  ylim(st_bbox(meuse)["ymin"], st_bbox(meuse)["ymax"])
```

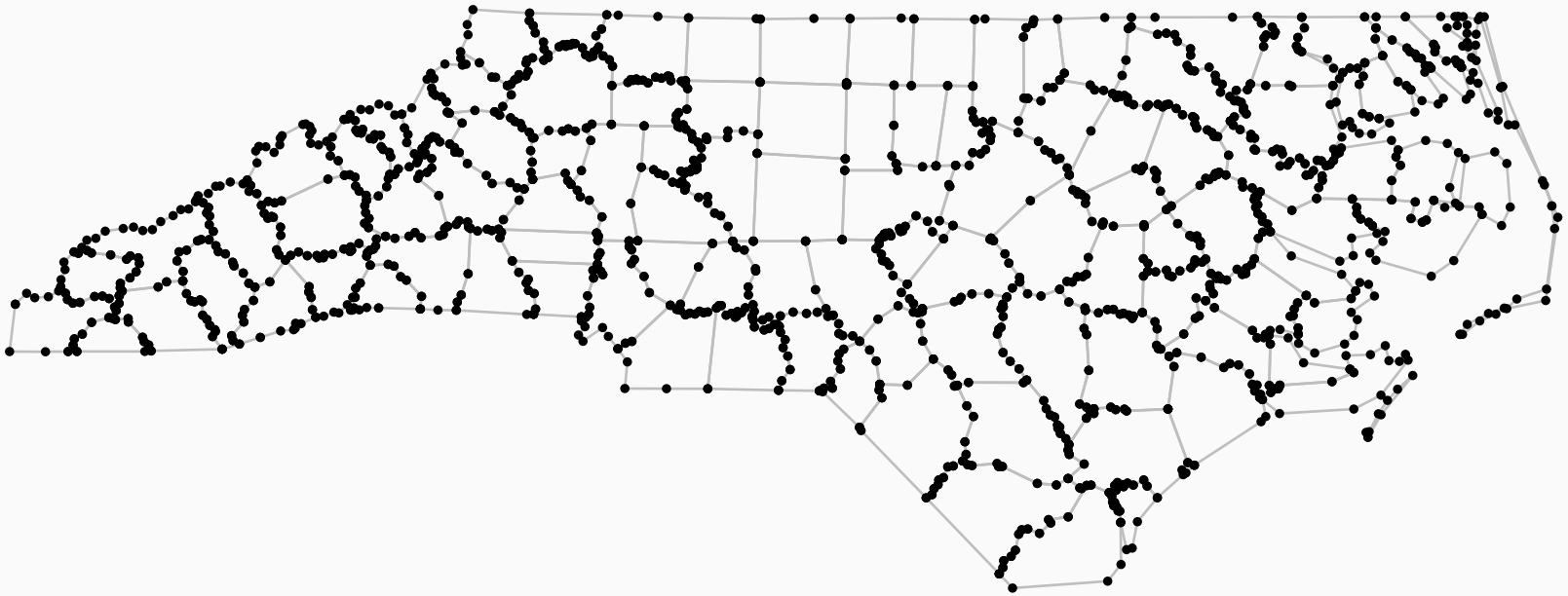


Geometry Manipulation

Casting

```
nc_pts = st_cast(nc, "MULTIPOINT")

nc_pts
## Simple feature collection with 100 features and 7 fields
## geometry type:  MULTIPOINT
## 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 20 features:
##           NAME BIR74 SID74 NWBIR74 BIR79 SID79 NWBIR79
## 1         Ashe  1091     1      10  1364     0      19
## 2    Alleghany   487     0      10   542     3      12
## 3        Surry  3188     5     208  3616     6     260
## 4    Currituck   508     1     123   830     2     145
## 5  Northampton  1421     9    1066  1606     3    1197
## 6     Hertford  1452     7     954  1838     5    1237
## 7       Camden   286     0     115   350     2     139
## 8        Gates   420     0     254   594     2     371
## 9       Warren   968     4     748  1190     2     844
## 10      Stokes  1612     1     160  2038     5     176
## 11     Caswell  1035     2     550  1253     2     597
## 12  Rockingham  4449    16    1243  5386     5    1369
## 13   Granville  1671     4     930  2074     4    1058
## 14      Person  1556     4     613  1790     4     650
## 15       Vance  2180     4    1179  2753     6    1492
## 16     Halifax  3608    18    2365  4463    17    2980
```

```
plot(st_geometry(nc), border='grey')
plot(st_geometry(nc_pts), pch=16, cex=0.5, add=TRUE)
```



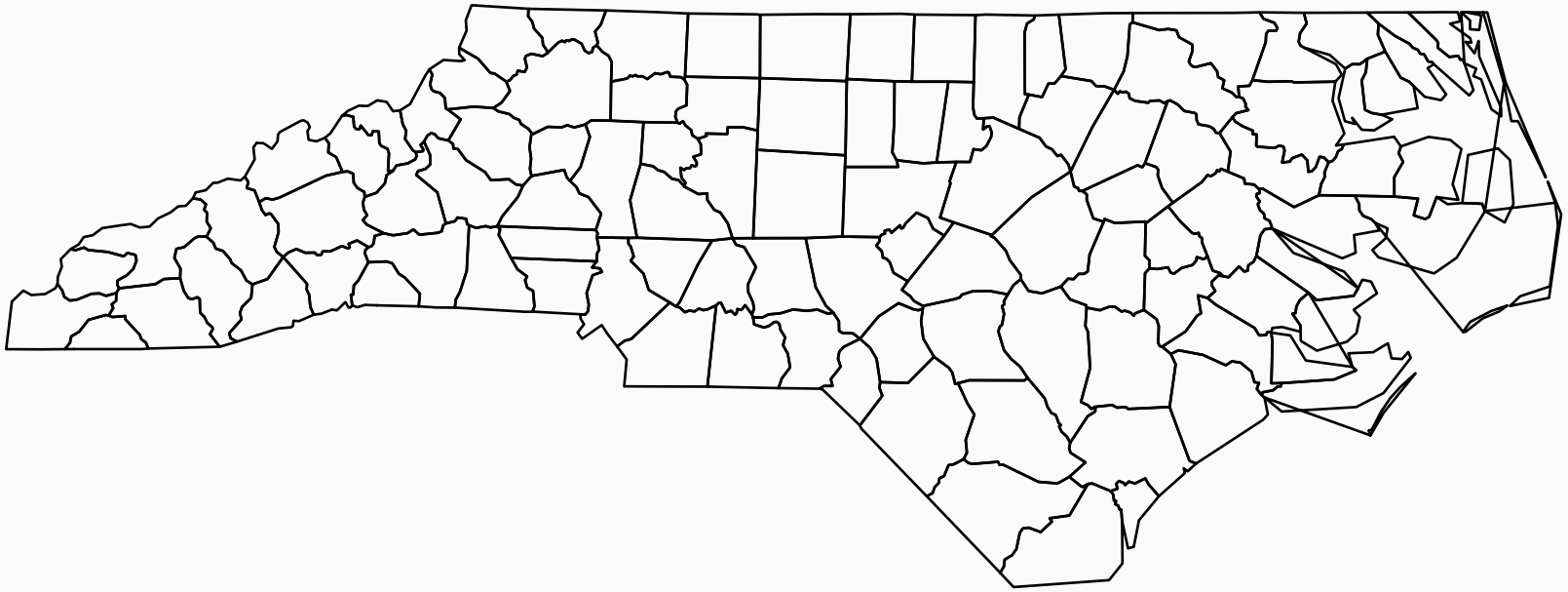
Casting - POINT

```
st_cast(nc, "POINT")
## Simple feature collection with 2529 features and 7 fields
## geometry type:  POINT
## 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 20 features:
##    NAME BIR74 SID74 NWBIR74 BIR79 SID79 NWBIR79
## 1  Ashe  1091     1      10  1364     0      19
## 2  Ashe  1091     1      10  1364     0      19
## 3  Ashe  1091     1      10  1364     0      19
## 4  Ashe  1091     1      10  1364     0      19
## 5  Ashe  1091     1      10  1364     0      19
## 6  Ashe  1091     1      10  1364     0      19
## 7  Ashe  1091     1      10  1364     0      19
## 8  Ashe  1091     1      10  1364     0      19
## 9  Ashe  1091     1      10  1364     0      19
## 10 Ashe  1091     1      10  1364     0      19
## 11 Ashe  1091     1      10  1364     0      19
## 12 Ashe  1091     1      10  1364     0      19
## 13 Ashe  1091     1      10  1364     0      19
## 14 Ashe  1091     1      10  1364     0      19
## 15 Ashe  1091     1      10  1364     0      19
## 16 Ashe  1091     1      10  1364     0      19
## 17 Ashe  1091     1      10  1364     0      19
## 18 Ashe  1091     1      10  1364     0      19
```

Casting - LINESTRING

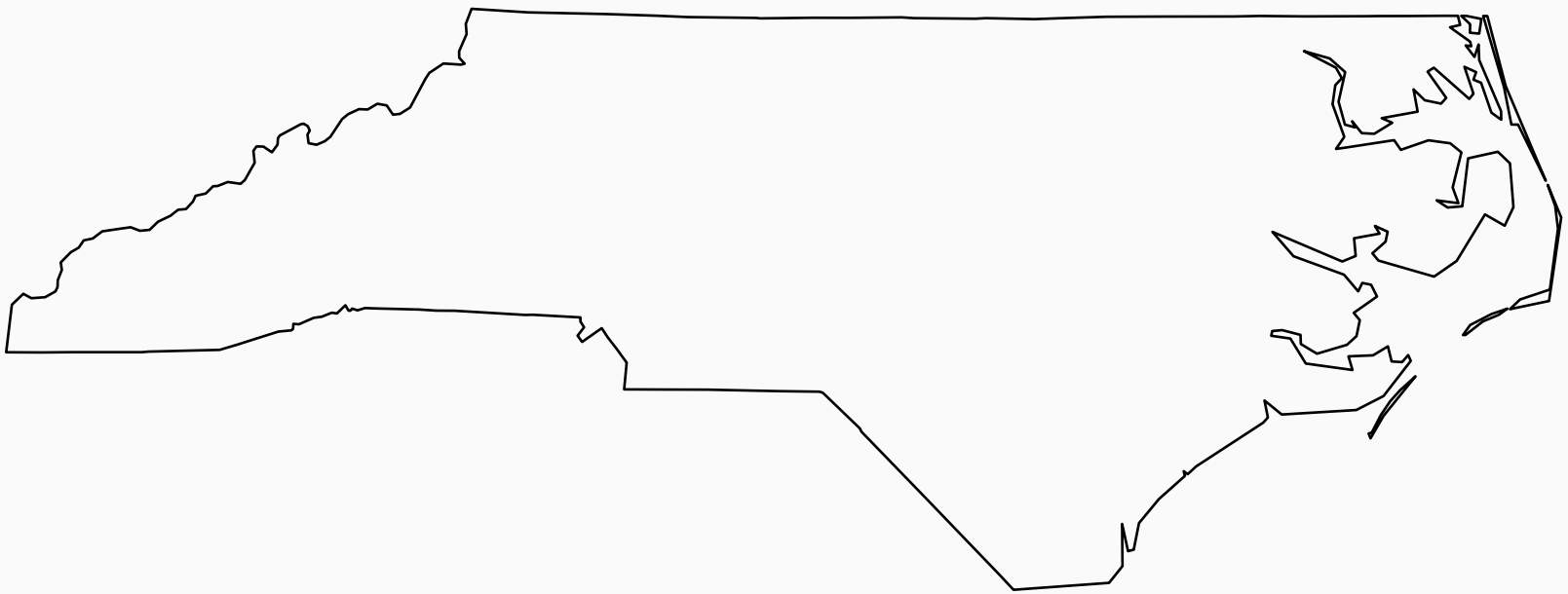
```
st_cast(nc, "LINESTRING")
## Simple feature collection with 100 features and 7 fields
## geometry type:  LINESTRING
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## epsg (SRID):    4267
## proj4string:    +proj=longlat +datum=NAD27 +no_defs
## First 20 features:
##           NAME BIR74 SID74 NWBIR74 BIR79 SID79 NWBIR79
## 1         Ashe  1091     1      10  1364     0      19
## 2    Alleghany   487     0      10   542     3      12
## 3        Surry  3188     5     208  3616     6     260
## 4    Currituck   508     1     123   830     2     145
## 5  Northampton  1421     9    1066  1606     3    1197
## 6     Hertford  1452     7     954  1838     5    1237
## 7       Camden   286     0     115   350     2     139
## 8        Gates   420     0     254   594     2     371
## 9       Warren   968     4     748  1190     2     844
## 10      Stokes  1612     1     160  2038     5     176
## 11     Caswell  1035     2     550  1253     2     597
## 12  Rockingham  4449    16    1243  5386     5    1369
## 13   Granville  1671     4     930  2074     4    1058
## 14      Person  1556     4     613  1790     4     650
## 15       Vance  2180     4    1179  2753     6    1492
## 16     Halifax  3608    18    2365  4463    17    2980
## 17  Pasquotank  1638     3     622  2275     4     933
## 18      Wilkes  3146     4     200  3725     7     222
```

```
st_cast(nc, "LINESTRING") %>% st_geometry() %>% plot()
```



Grouping Features

```
nc_state = st_union(nc)
plot(nc_state)
```

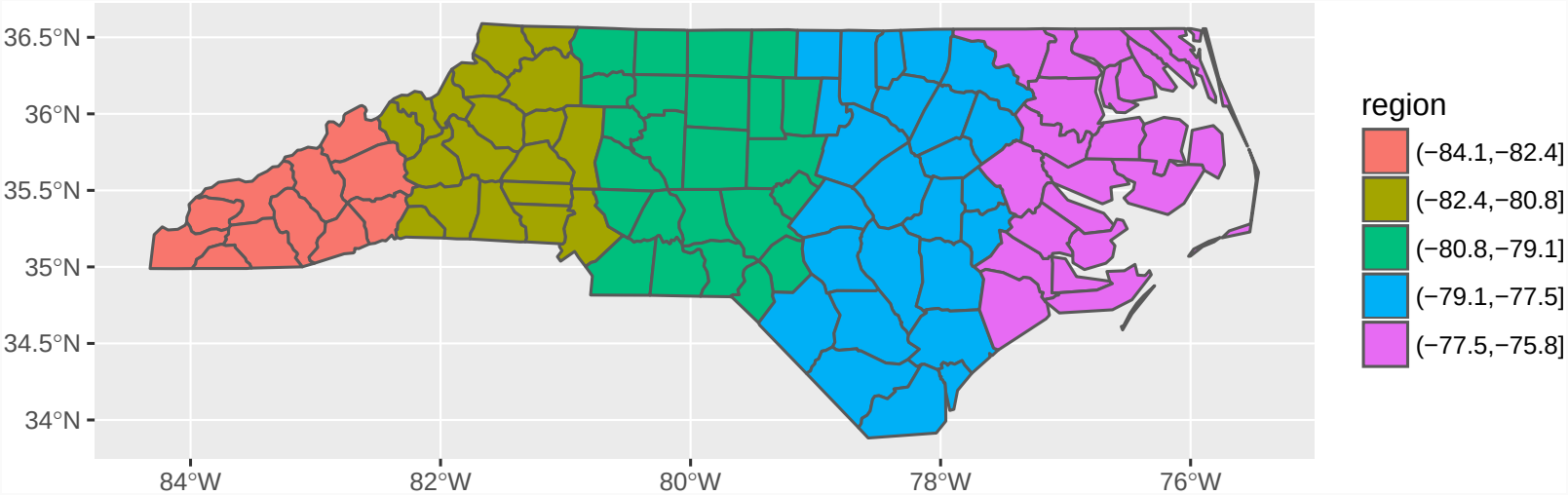


```
nc_state
## Geometry set for 1 feature
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## epsg (SRID):    4267
## proj4string:    +proj=longlat +datum=NAD27 +no_defs
```

More Grouping

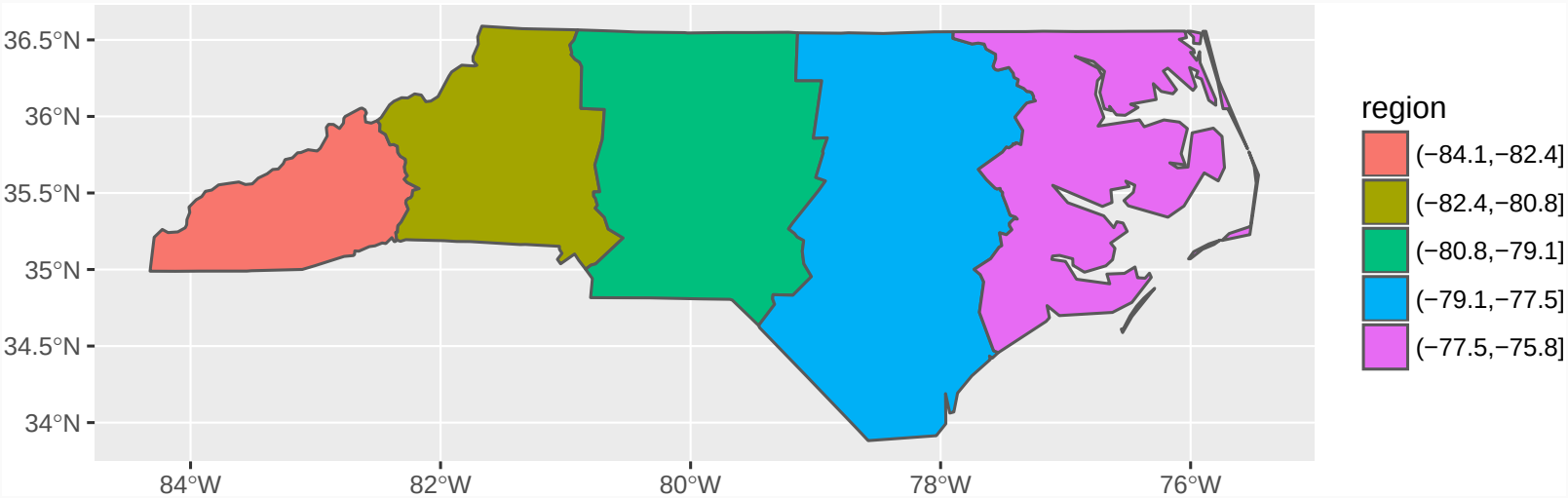
```
nc_cut = nc %>%
  cbind(nc %>% st_centroid() %>% st_coordinates()) %>%
  mutate(region = cut(X, breaks = 5))

nc_cut
## Simple feature collection with 100 features and 10 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 20 features:
##           NAME BIR74 SID74 NWBIR74 BIR79 SID79 NWBIR79         X
## 1         Ashe  1091     1      10  1364     0      19 -81.49826
## 2    Alleghany   487     0      10   542     3      12 -81.12515
## 3        Surry  3188     5     208  3616     6     260 -80.68575
## 4    Currituck   508     1     123   830     2     145 -76.02750
## 5  Northampton  1421     9    1066  1606     3    1197 -77.41056
## 6     Hertford  1452     7     954  1838     5    1237 -76.99478
## 7       Camden   286     0     115   350     2     139 -76.23435
## 8        Gates   420     0     254   594     2     371 -76.70448
## 9       Warren   968     4     748  1190     2     844 -78.11043
## 10      Stokes  1612     1     160  2038     5     176 -80.23428
## 11     Caswell  1035     2     550  1253     2     597 -79.33477
## 12  Rockingham  4449    16    1243  5386     5    1369 -79.77038
## 13   Granville  1671     4     930  2074     4    1058 -78.65647
## 14      Person  1556     4     613  1790     4     650 -78.97684
```

```
ggplot(nc_cut) +
  geom_sf(aes(fill=region))
```



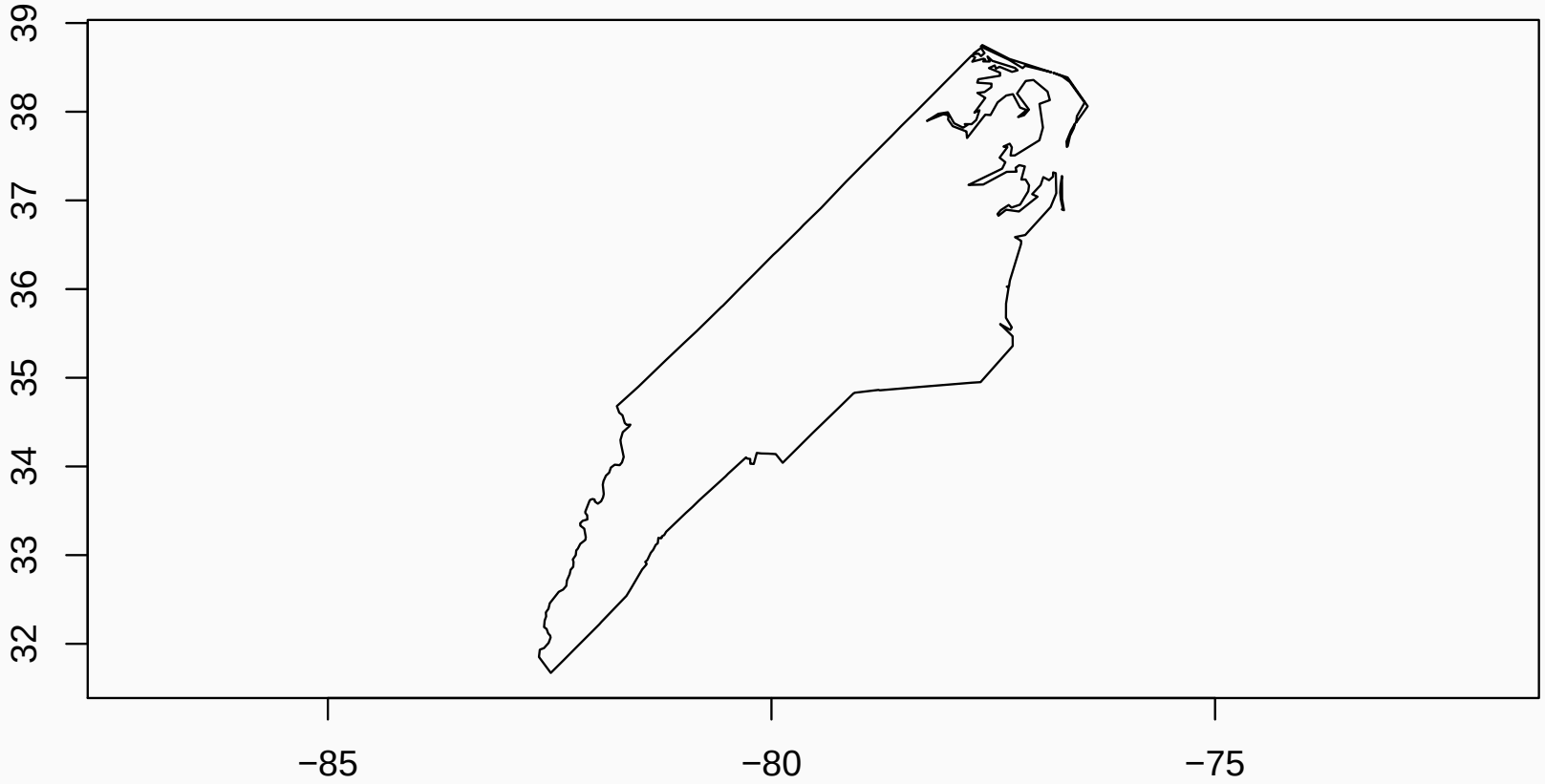
dplyr and sf - BFFs

```
nc_cut %>%
  group_by(region) %>%
  summarize(geometry = st_union(geometry)) %>%
  ggplot() + geom_sf(aes(fill=region))
```



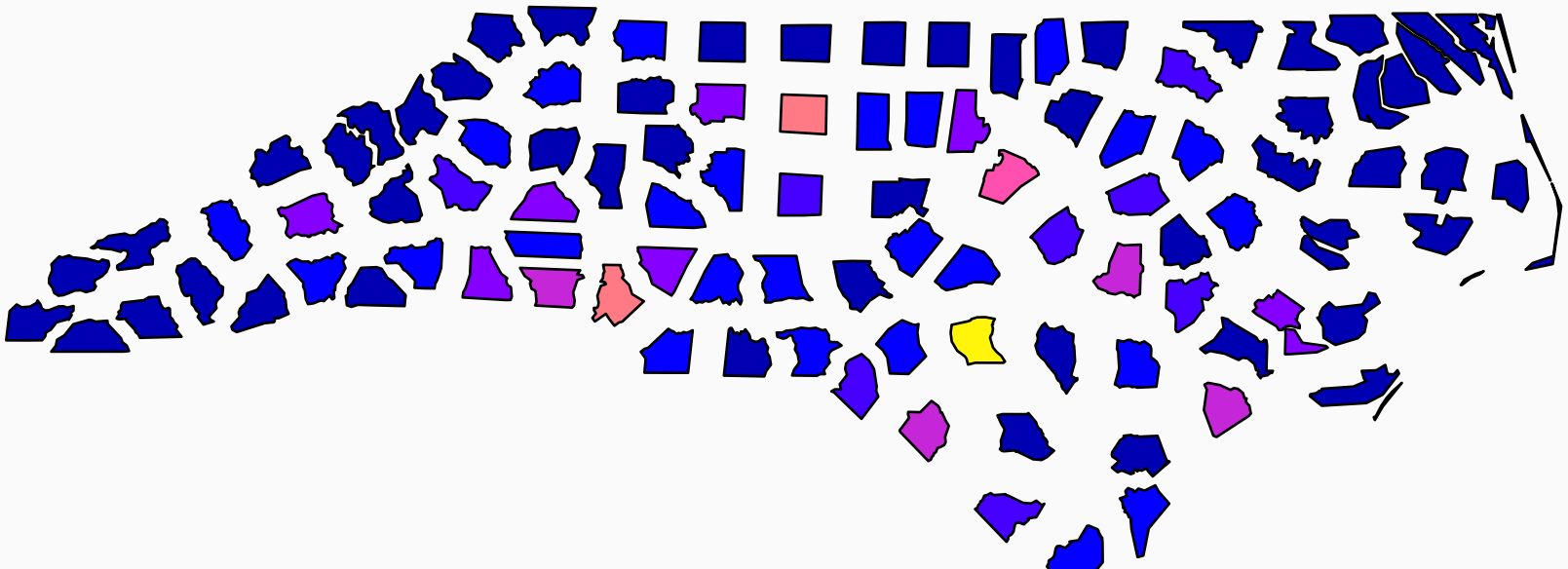
Affine Transfomations

```
rotate = function(a) matrix(c(cos(a), sin(a), -sin(a), cos(a)), 2, 2)

ctrd = st_centroid(nc_state)
state_rotate = (nc_state - ctrd) * rotate(-pi/4) + ctrd
plot(state_rotate, axes=TRUE)
```



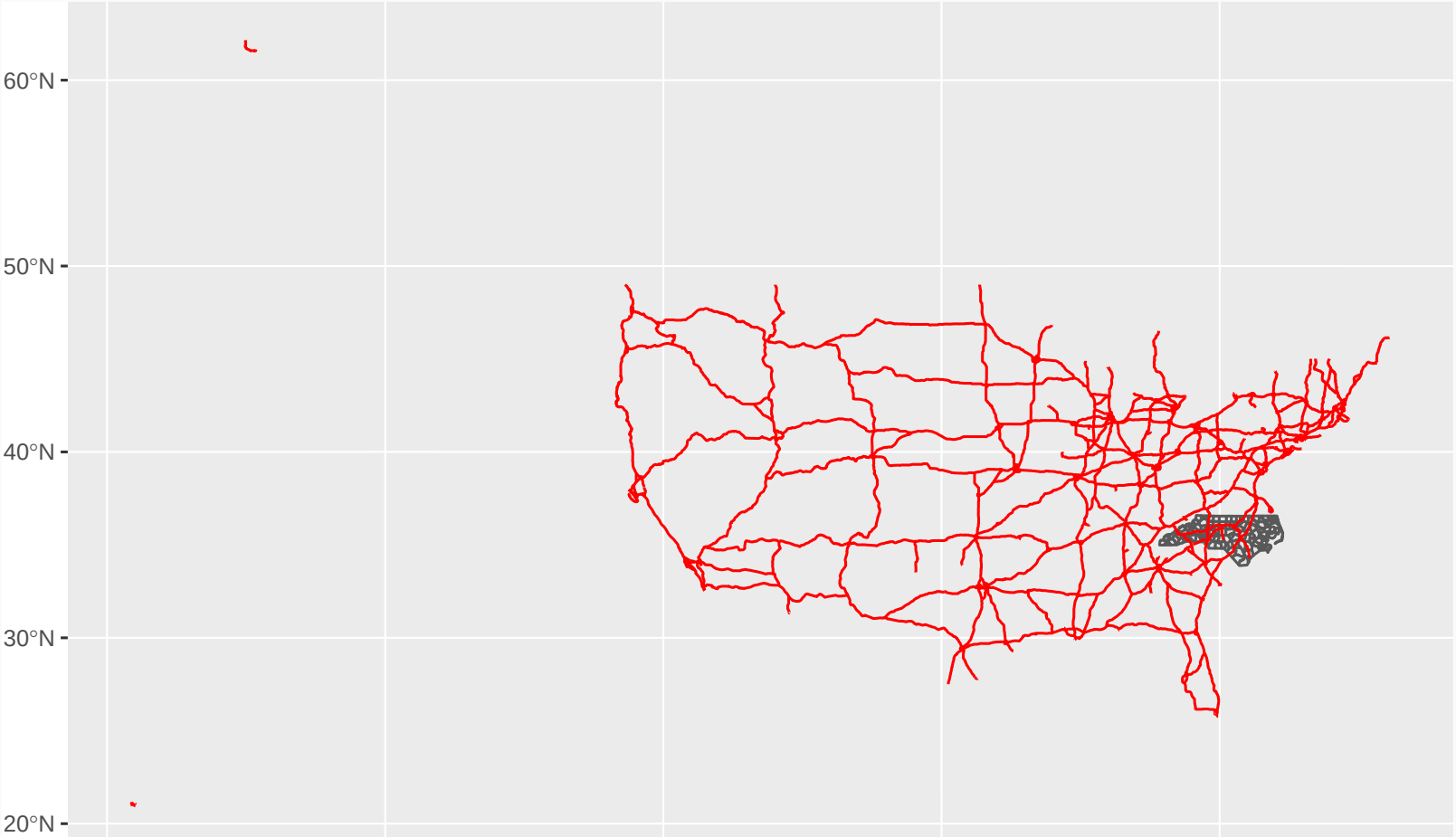
Scaling Size

```
ctrd = st_geometry(st_centroid(nc))
area = st_area(nc) %>% strip_attrs()
nc_scaled = nc
for(i in 1:nrow(nc))
  nc_scaled$geometry[[i]] = ((st_geometry(nc[i,]) - ctrd[i]) *
                               sqrt(min(area)/area[i]) + ctrd[i])[[1]]

plot(nc_scaled[,"SID79"])
```



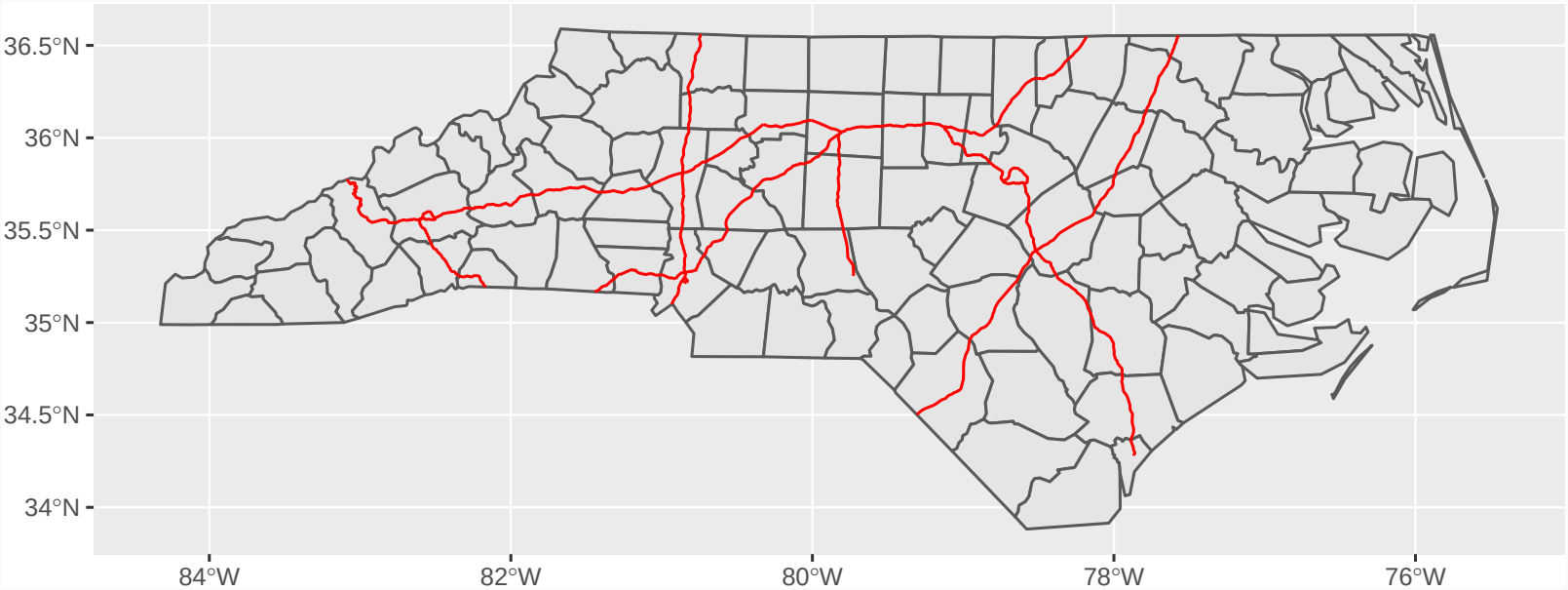
Back to the highways

```
hwy = st_read("../../data/gis/us_interstates/", quiet=TRUE, stringsAsFactors=FALSE) %>

ggplot() +
  geom_sf(data=nc) +
  geom_sf(data=hwy, col='red')
```



NC Interstate Highways

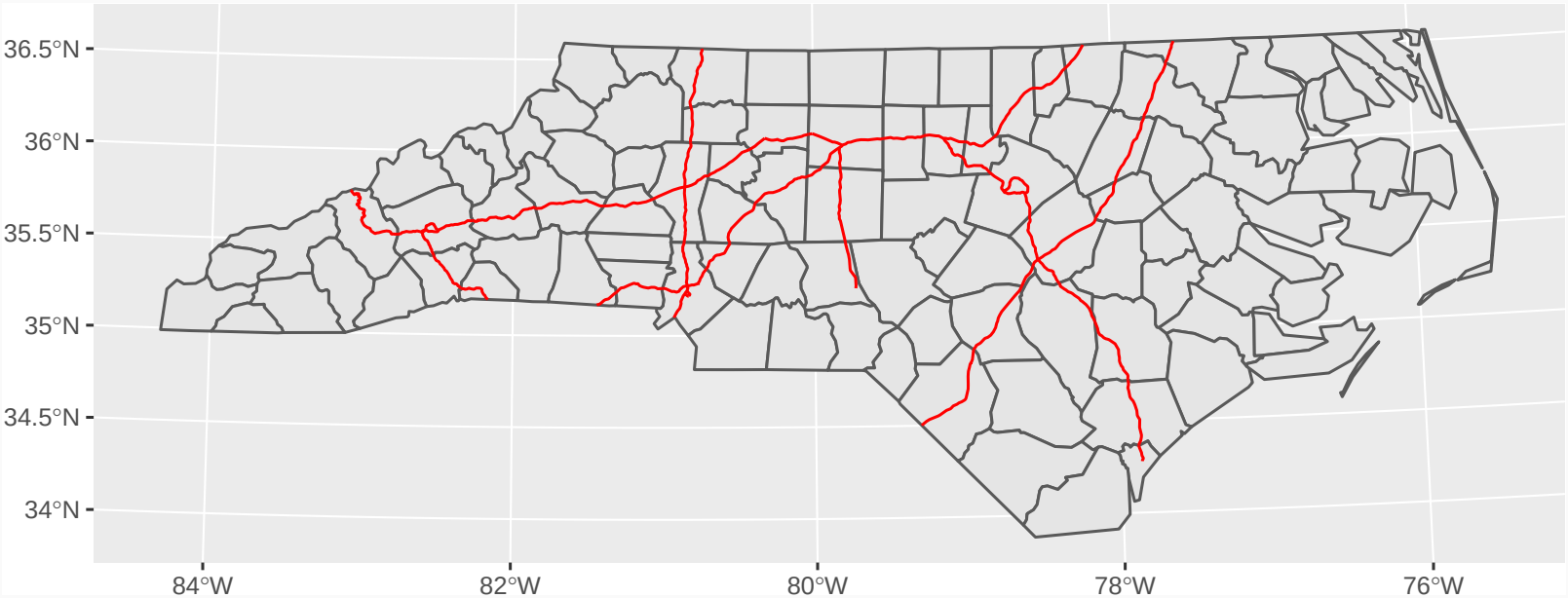
```
hwy_nc = st_intersection(hwy, nc)

ggplot() +
  geom_sf(data=nc) +
  geom_sf(data=hwy_nc, col='red')
```




```
hwy_nc
## Simple feature collection with 56 features and 10 fields
## geometry type:  GEOMETRY
## dimension:      XY
## bbox:           xmin: -83.09008 ymin: 34.2791 xmax: -77.57348 ymax: 36.56092
```

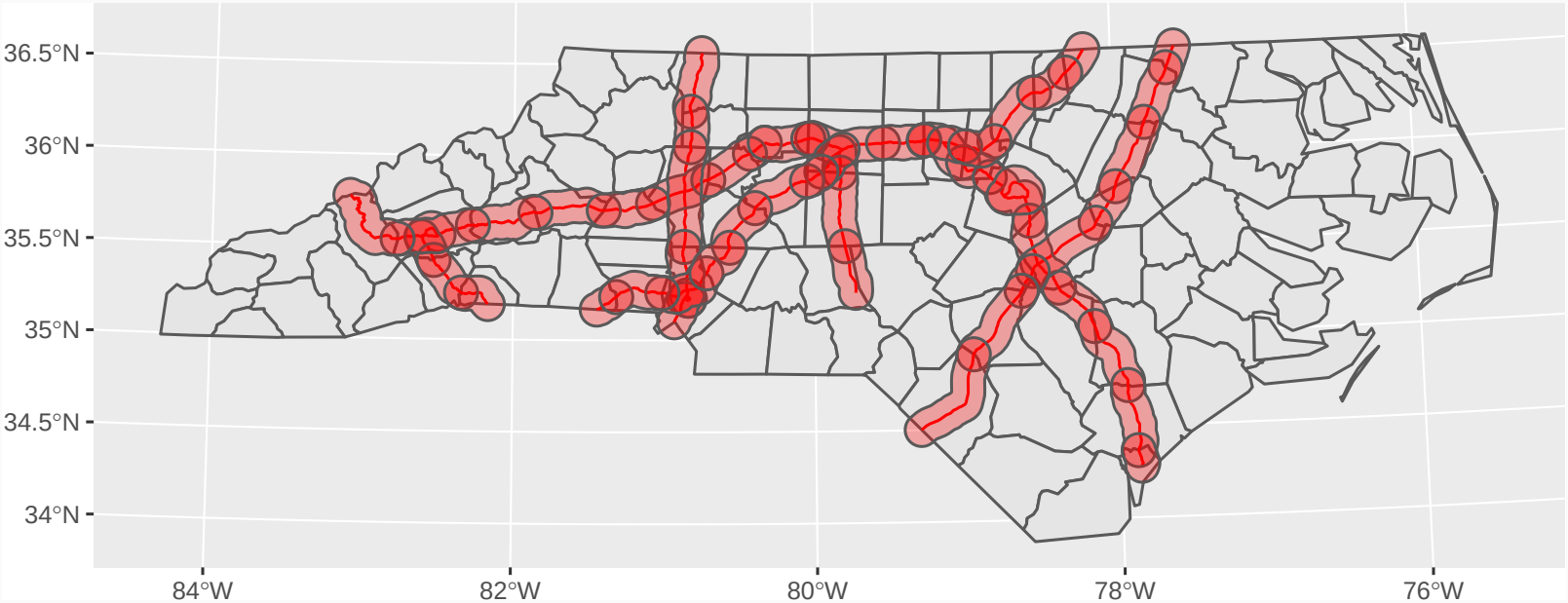
Counties near the interstate (Projection)

```
nc_utm  = st_transform(nc,  "+proj=utm +zone=17 +datum=NAD83 +units=m +no_defs")
hwy_utm = st_transform(hwy, "+proj=utm +zone=17 +datum=NAD83 +units=m +no_defs")

hwy_nc_utm = st_intersection(nc_utm, hwy_utm)

ggplot() +
  geom_sf(data=nc_utm) +
  geom_sf(data=hwy_nc_utm, col='red')
```



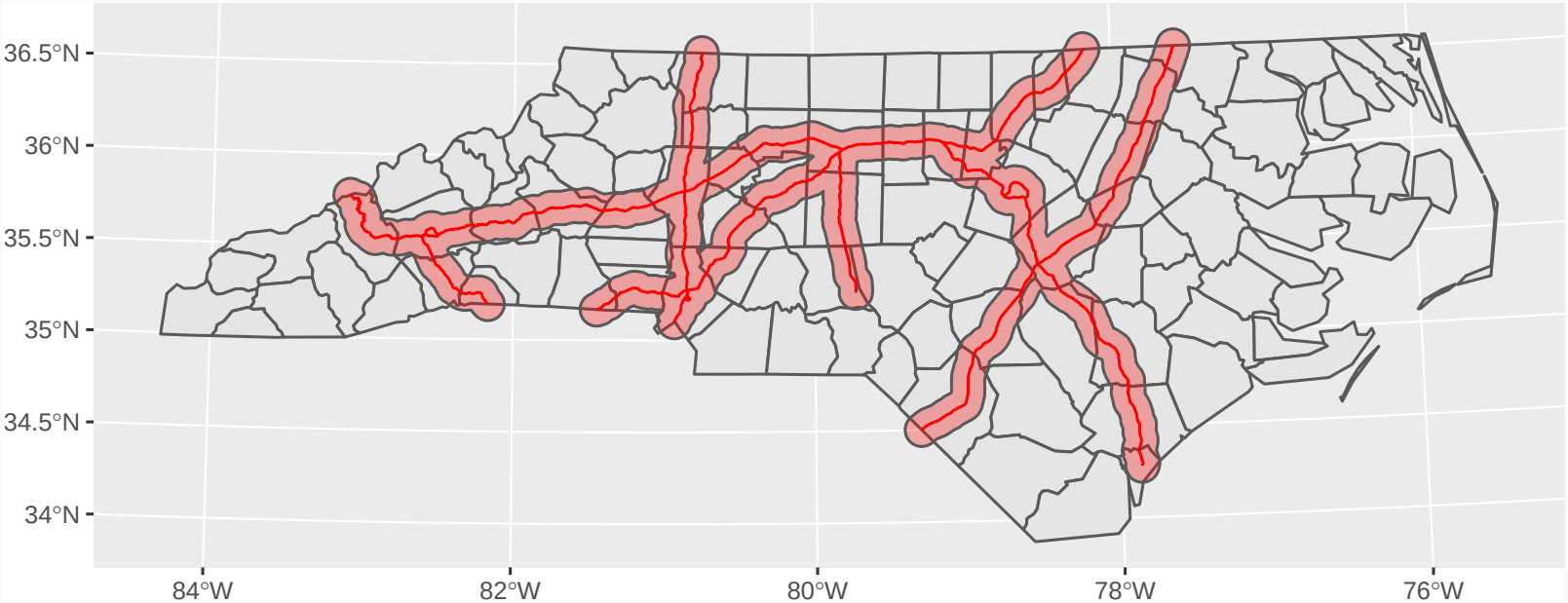
Counties near the interstate (Buffering)

```
hwy_nc_buffer = st_buffer(hwy_nc_utm, 10000)

ggplot() +
  geom_sf(data=nc_utm) +
  geom_sf(data=hwy_nc_utm, color='red') +
  geom_sf(data=hwy_nc_buffer, fill='red', alpha=0.3)
```



Counties near the interstate (Buffering + Union)

```
hwy_nc_buffer = st_buffer(hwy_nc_utm, 10000) %>% st_union() %>% st_sf()

ggplot() +
  geom_sf(data=nc_utm) +
  geom_sf(data=hwy_nc_utm, color='red') +
  geom_sf(data=hwy_nc_buffer, fill='red', alpha=0.3)
```



Exercise 1

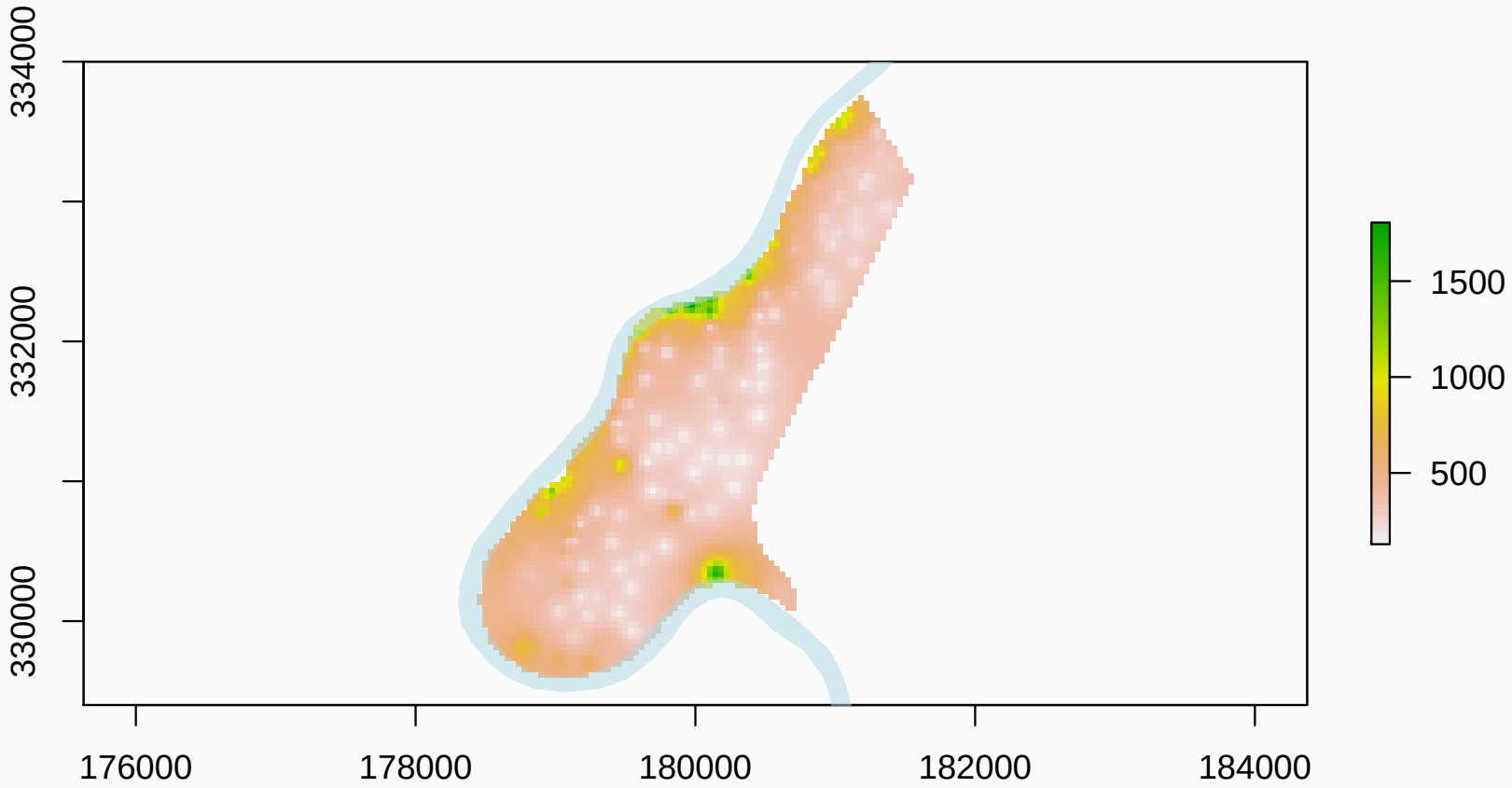
How many counties in North Carolina are within 5, 10, 20, or 50 km of an interstate highway?

Raster Data

Example data - Meuse

```
meuse_rast = raster(system.file("external/test.grd", package="raster"))

meuse_rast
## class       : RasterLayer
## dimensions  : 115, 80, 9200  (nrow, ncol, ncell)
## resolution  : 40, 40  (x, y)
## extent      : 178400, 181600, 329400, 334000  (xmin, xmax, ymin, ymax)
## coord. ref. : +init=epsg:28992 +towgs84=565.237,50.0087,465.658,-0.406857,0.350733,
## data source : /usr/local/lib/R/3.3/site-library/raster/external/test.grd
## names       : test
## values      : 128.434, 1805.78  (min, max)
```

```r
plot(meuse_rast)
plot(meuse_riv, add=TRUE, col=adjustcolor("lightblue",alpha.f = 0.5), border=NA)
```



raster class

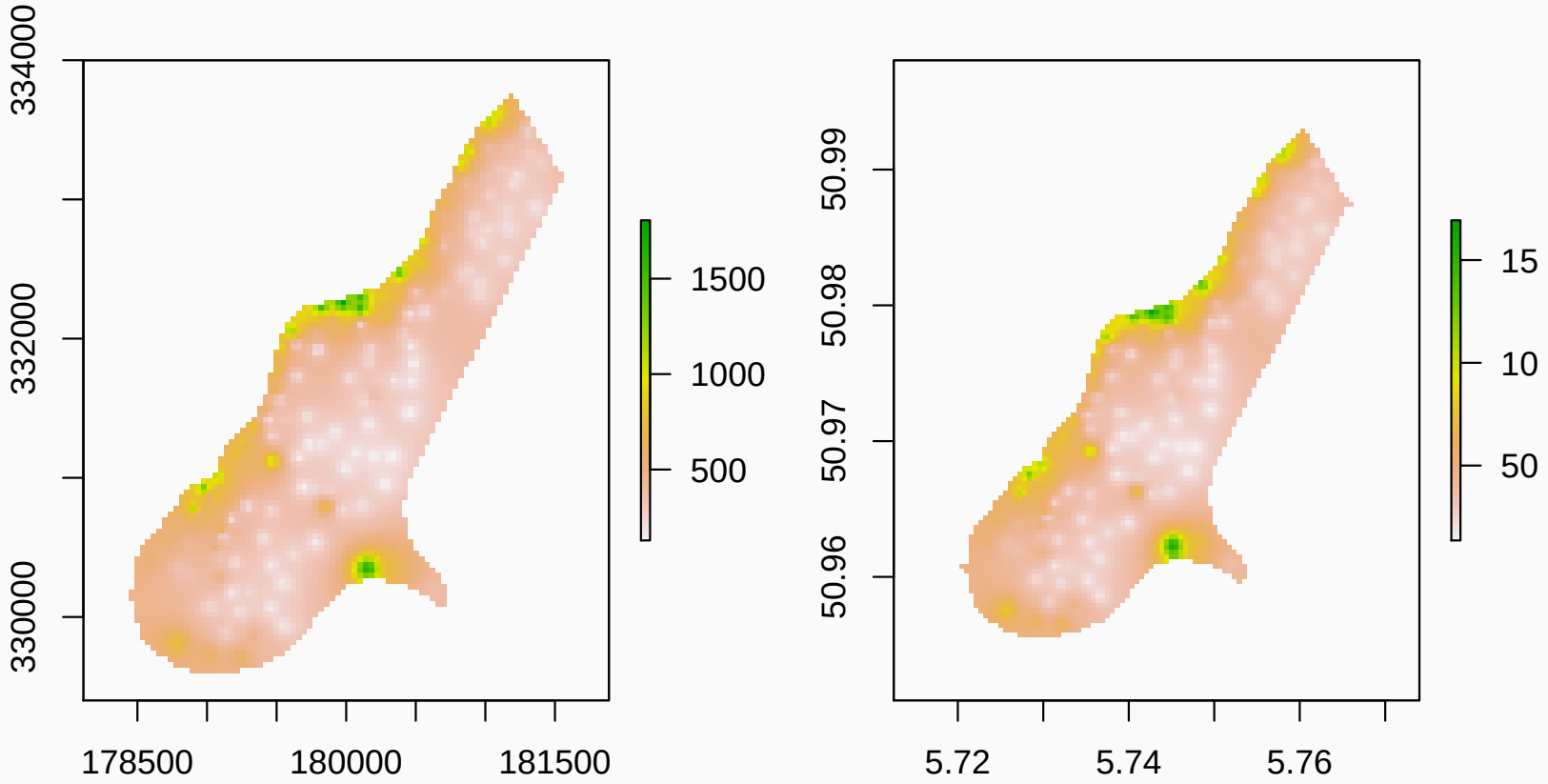
```
str(meuse_rast)
## Formal class 'RasterLayer' [package "raster"] with 12 slots
##   ..@ file    :Formal class '.RasterFile' [package "raster"] with 13 slot
##   .. .. ..@ name        : chr "/usr/local/lib/R/3.3/site-library/raster/e
##   .. .. ..@ datanotation: chr "FLT4S"
##   .. .. ..@ byteorder   : Named chr "little"
##   .. .. .. ..- attr(*, "names")= chr "value"
##   .. .. ..@ nodatavalue : num -3.4e+38
##   .. .. ..@ NAchanged   : logi FALSE
##   .. .. ..@ nbands      : int 1
##   .. .. ..@ bandorder   : Named chr "BIL"
##   .. .. .. ..- attr(*, "names")= chr "value"
##   .. .. ..@ offset      : int 0
##   .. .. ..@ toptobottom : logi TRUE
##   .. .. ..@ blockrows   : int 0
##   .. .. ..@ blockcols   : int 0
##   .. .. ..@ driver      : chr "raster"
##   .. .. ..@ open        : logi FALSE
##   ..@ data    :Formal class '.SingleLayerData' [package "raster"] with 13
##   .. .. ..@ values    : logi(0)
##   .. .. ..@ offset    : num 0
##   .. .. ..@ gain      : num 1
##   .. .. ..@ inmemory  : logi FALSE
##   .. .. ..@ fromdisk  : logi TRUE
```

raster features

```
extent(meuse_rast)
## class       : Extent
## xmin        : 178400
## xmax        : 181600
## ymin        : 329400
## ymax        : 334000

dim(meuse_rast)
## [1] 115  80   1

res(meuse_rast)
## [1] 40 40

projection(meuse_rast)
## [1] "+init=epsg:28992 +towgs84=565.237,50.0087,465.658,-0.406857,0.350733,-1.87035,

meuse_rast[20,]
##  [1]      NA      NA      NA      NA      NA      NA      NA      NA
##  [9]      NA      NA      NA      NA      NA      NA      NA      NA
## [17]      NA      NA      NA      NA      NA      NA      NA      NA
## [25]      NA      NA      NA      NA      NA      NA      NA      NA
## [33]      NA      NA      NA      NA      NA      NA      NA      NA
## [41]      NA      NA      NA      NA      NA      NA      NA      NA
## [49]      NA      NA      NA      NA      NA      NA      NA      NA
## [57]      NA      NA      NA 749.536 895.292 791.145 607.186 511.044
## [65] 468.404 399.325 350.362 306.180 300.483 310.082 283.940 285.771
## [73] 304.709 309.690 301.799 308.753 328.357 345.611      NA      NA
```

Rasters and Projections

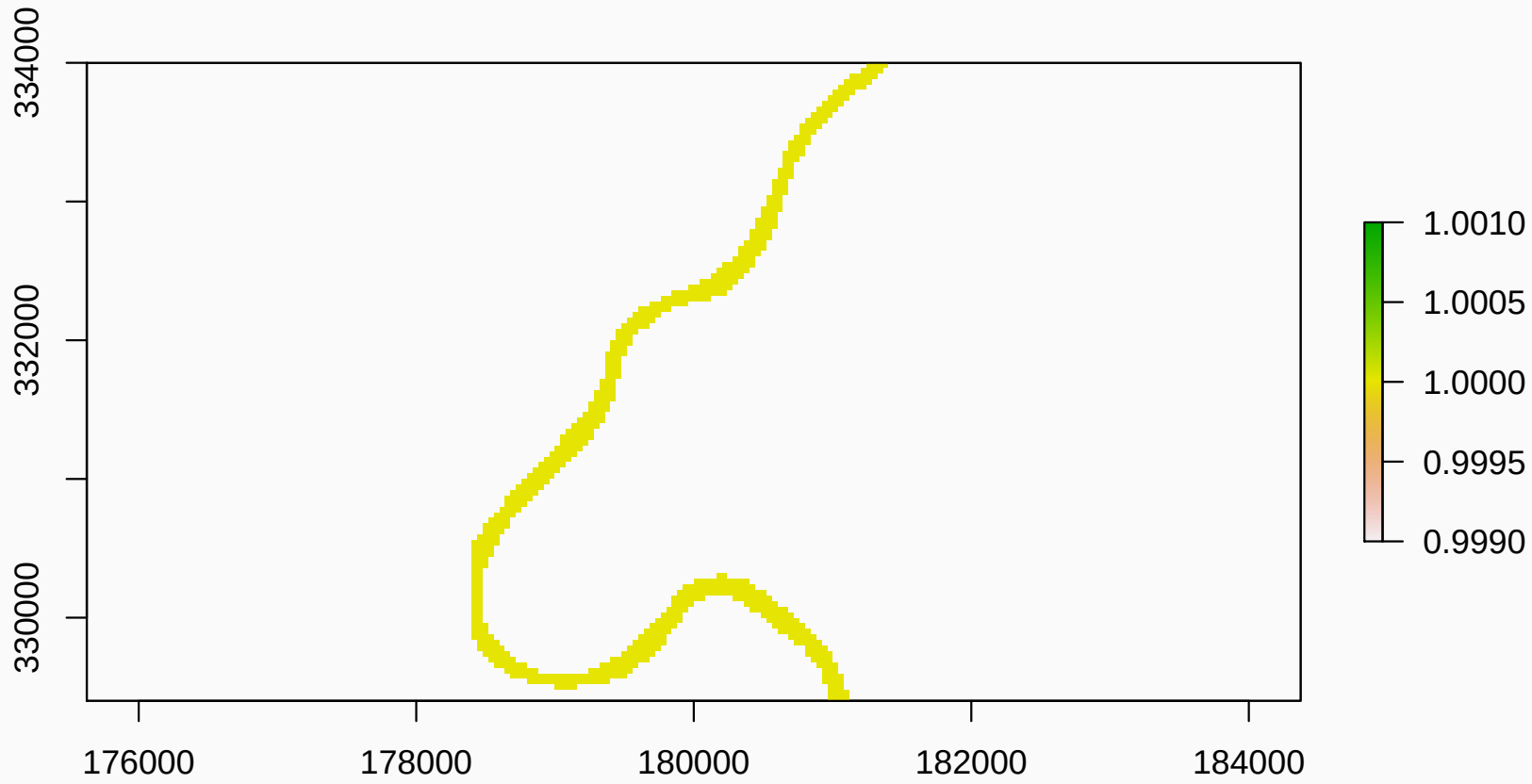
```
meuse_rast_ll = projectRaster(meuse_rast, crs="+proj=longlat +datum=NAD27 +no_defs")

par(mfrow=c(1,2))
plot(meuse_rast)
plot(meuse_rast_ll)
```



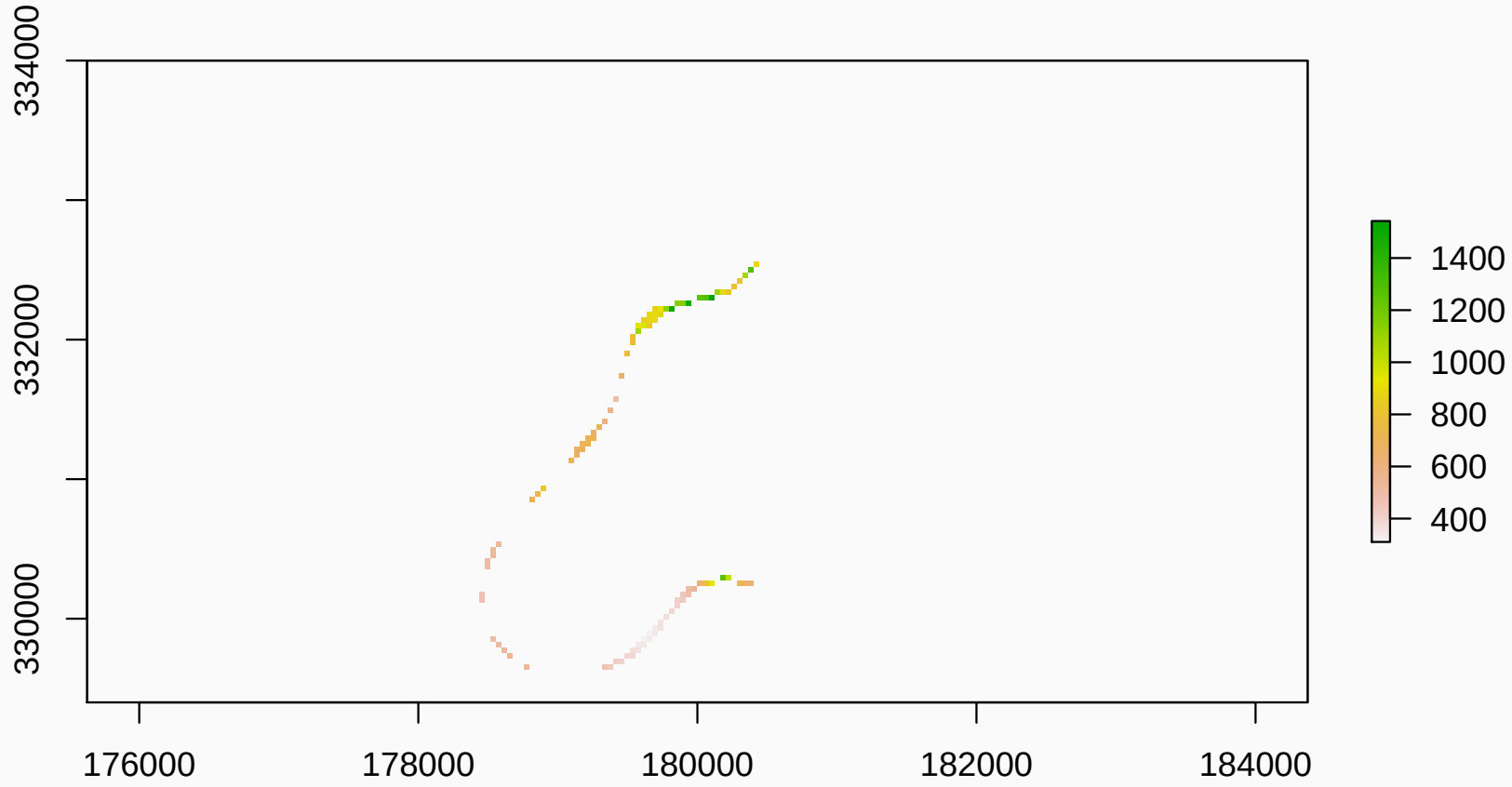
```
meuse_rast
## class       : RasterLayer
## dimensions  : 115, 80, 9200  (nrow, ncol, ncell)
## resolution  : 40, 40  (x, y)
## extent      : 178400, 181600, 329400, 334000  (xmin, xmax, ymin, ymax)
## coord. ref. : +init=epsg:28992 +towgs84=565.237,50.0087,465.658,-0.406857,0.350733,
## data source : /usr/local/lib/R/3.3/site-library/raster/external/test.grd
## names       : test
## values      : 128.434, 1805.78  (min, max)

meuse_rast_ll
## class       : RasterLayer
## dimensions  : 131, 91, 11921  (nrow, ncol, ncell)
## resolution  : 0.000569, 0.00036  (x, y)
## extent      : 5.717362, 5.769141, 50.95089, 50.99805  (xmin, xmax, ymin, ymax)
## coord. ref. : +proj=longlat +datum=NAD27 +no_defs +ellps=clrk66 +nadgrids=@conus,@a
## data source : in memory
## names       : test
## values      : 135.647, 1693.578  (min, max)
```

Simple Features ⟷ Rasters

```
meuse_riv_rast = rasterize(meuse_riv, meuse_rast)
## Error in (function (classes, fdef, mtable) : unable to find an inherited method for

meuse_riv_rast = rasterize(as(meuse_riv, "Spatial"), meuse_rast)
plot(meuse_riv_rast)
```



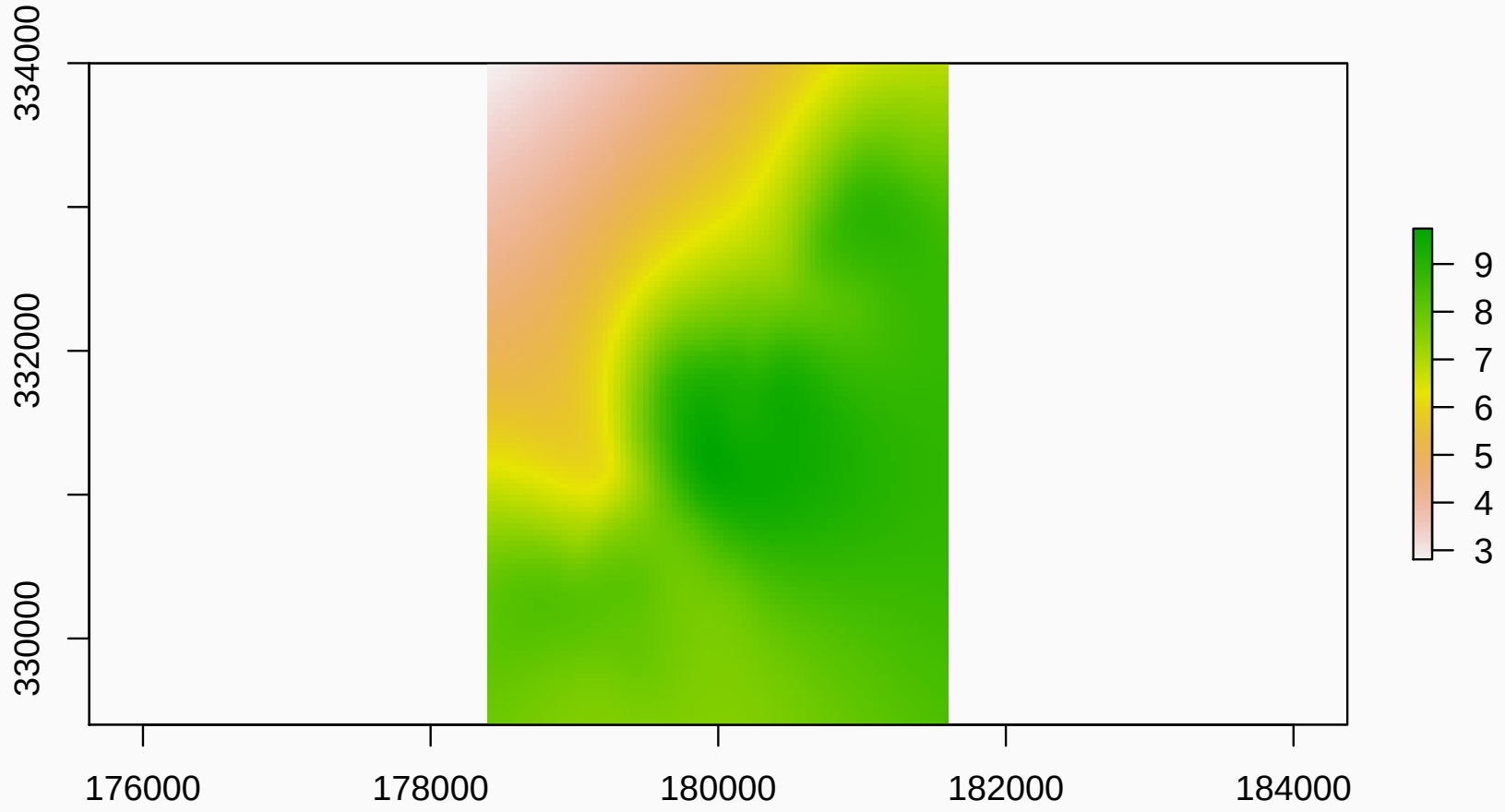
```r
sub = !is.na(meuse_riv_rast[]) & !is.na(meuse_rast[])

river_obs = meuse_rast
river_obs[!sub] = NA

plot(river_obs)
```




```r
xyFromCell(river_obs, which(sub))
##              x      y
##  [1,] 180420 332540
```

```
head(meuse)
## Simple feature collection with 6 features and 12 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: 181025 ymin: 333260 xmax: 181390 ymax: 333611
## epsg (SRID):    28992
## proj4string:    +proj=sterea +lat_0=52.15616055555555 +lon_0=5.38763888888889 +k=0.
##   cadmium copper lead zinc  elev       dist   om ffreq soil lime
## 1    11.7     85  299 1022 7.909 0.00135803 13.6     1    1    1
## 2     8.6     81  277 1141 6.983 0.01222430 14.0     1    1    1
## 3     6.5     68  199  640 7.800 0.10302900 13.0     1    1    1
## 4     2.6     81  116  257 7.655 0.19009400  8.0     1    2    0
## 5     2.8     48  117  269 7.480 0.27709000  8.7     1    2    0
## 6     3.0     61  137  281 7.791 0.36406700  7.8     1    2    0
##   landuse dist.m            geometry
## 1      Ah     50 POINT(181072 333611)
## 2      Ah     30 POINT(181025 333558)
## 3      Ah    150 POINT(181165 333537)
## 4      Ga    270 POINT(181298 333484)
## 5      Ah    380 POINT(181307 333330)
## 6      Ga    470 POINT(181390 333260)

head(st_coordinates(meuse))
##        X      Y
## 1 181072 333611
## 2 181025 333558
## 3 181165 333537
```

```r
library(fields)

tps = Tps(x = st_coordinates(meuse), Y=meuse$elev)
pred_grid = xyFromCell(meuse_rast, seq_along(meuse_rast))

meuse_elev_pred = meuse_rast
meuse_elev_pred[] = predict(tps, pred_grid)

plot(meuse_elev_pred)
```



Hacky Crap

```
p = rasterToPolygons(meuse_elev_pred) %>% st_as_sf()
grid.arrange(
  ggplot() + geom_sf(data=meuse, aes(color=elev), size=0.1),
  ggplot() + geom_sf(data=p, aes(fill=test), color=NA),
  ncol=2
)
```