

Lecture 17

Spatial Data and Cartography (Part 2)

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Plotting

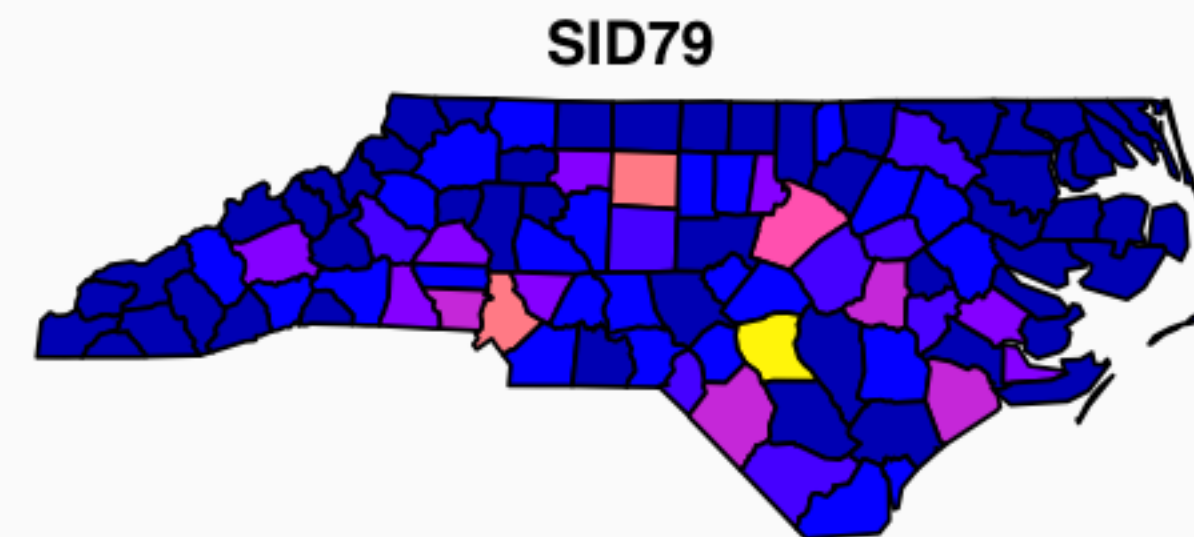
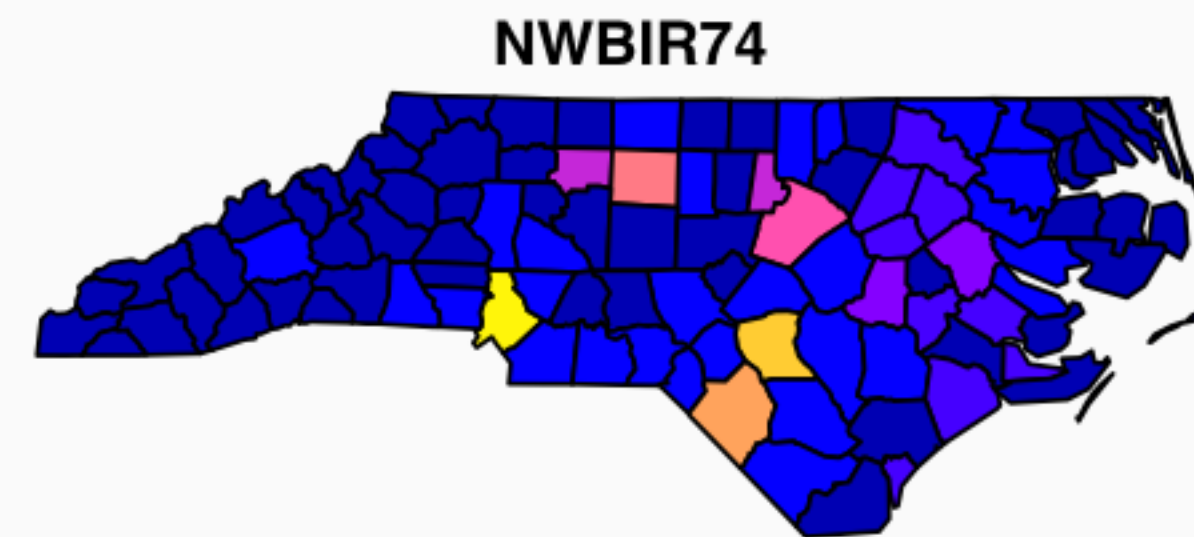
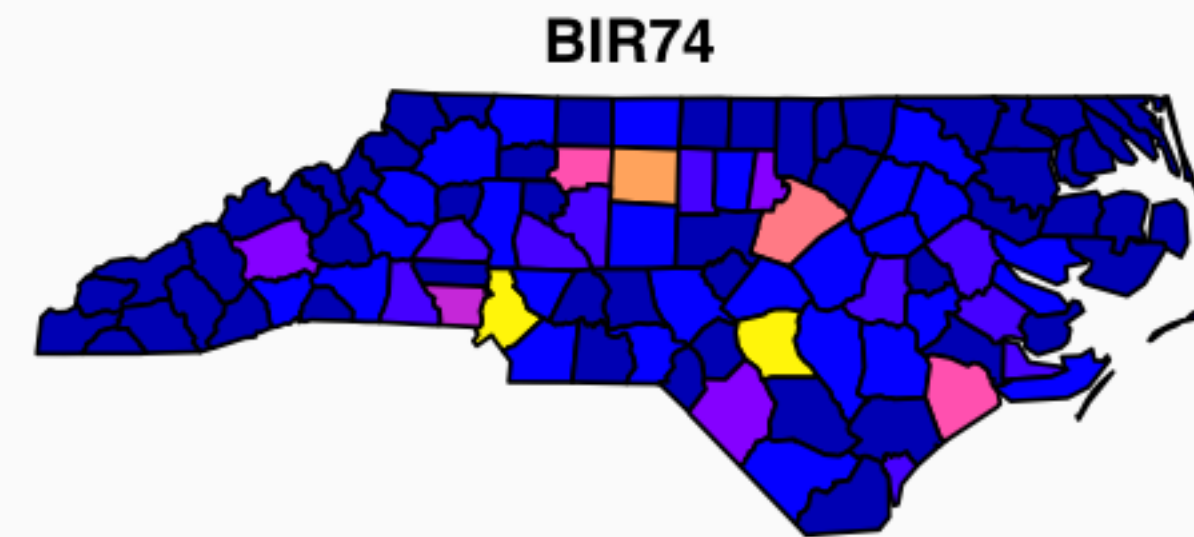
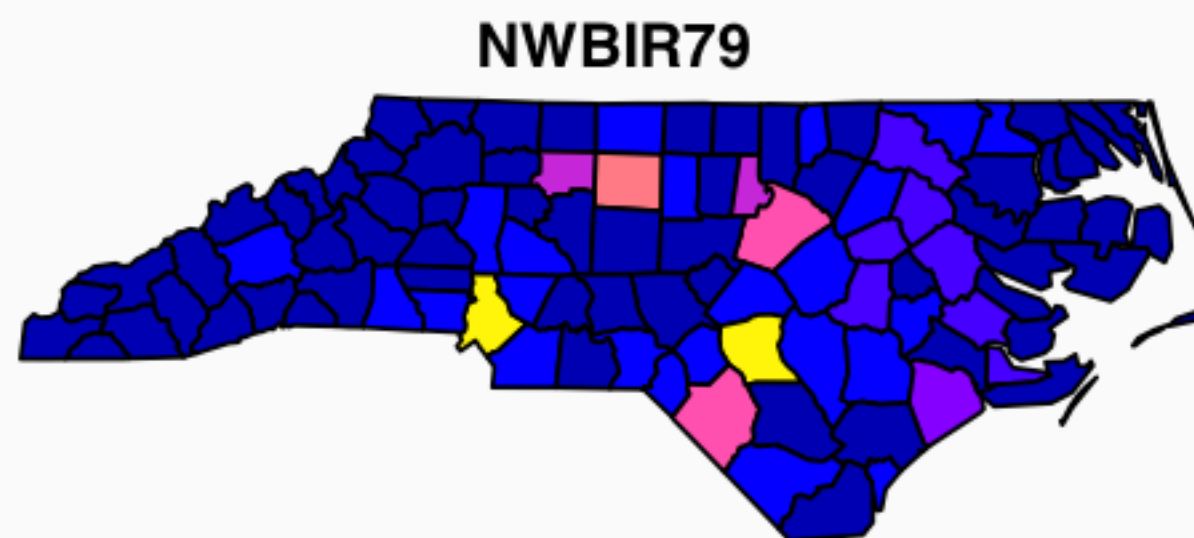
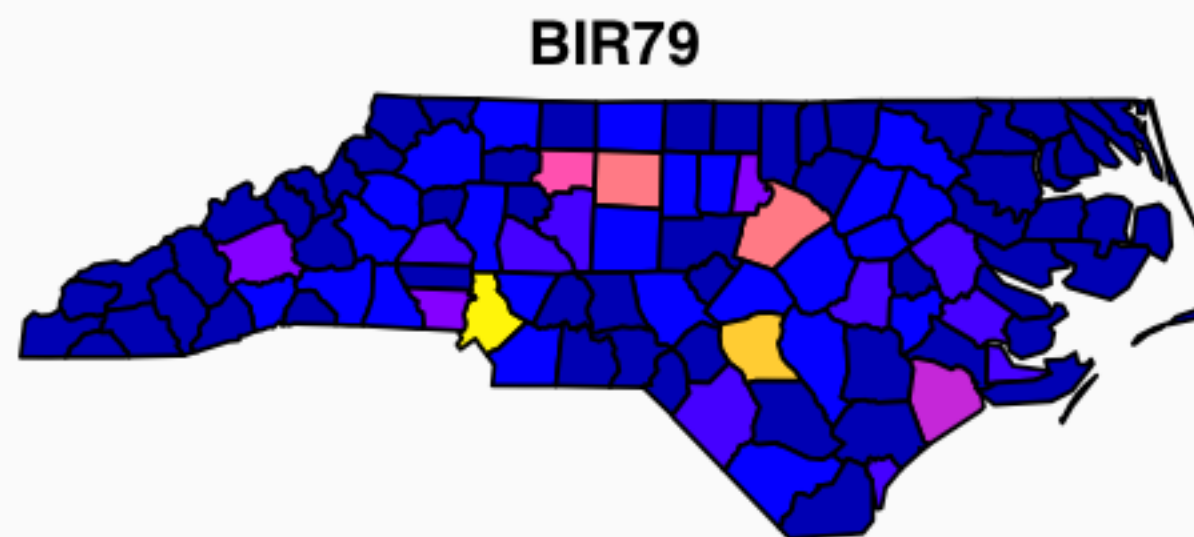
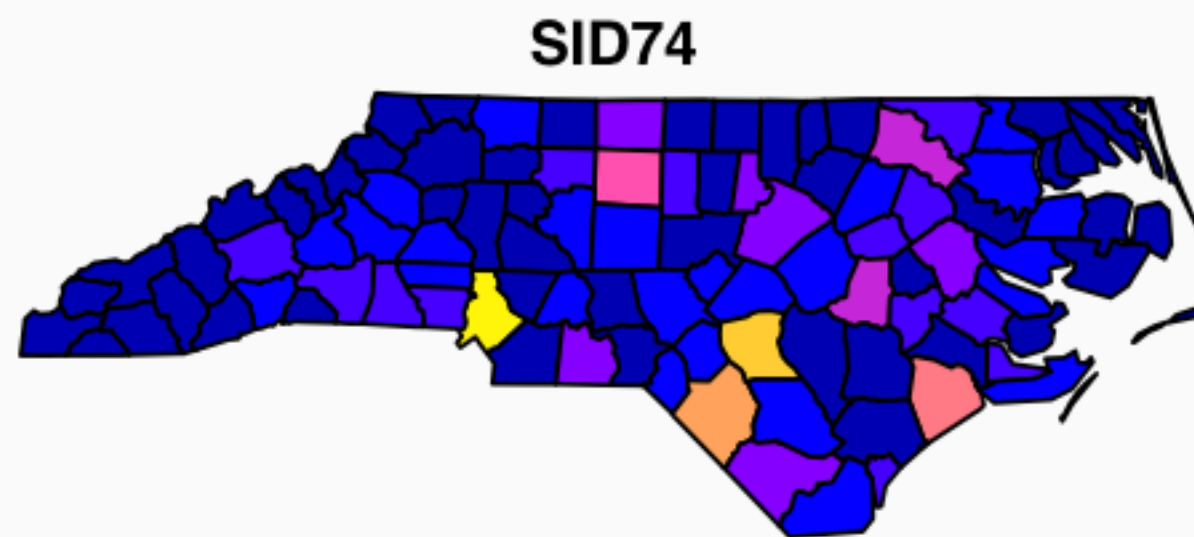
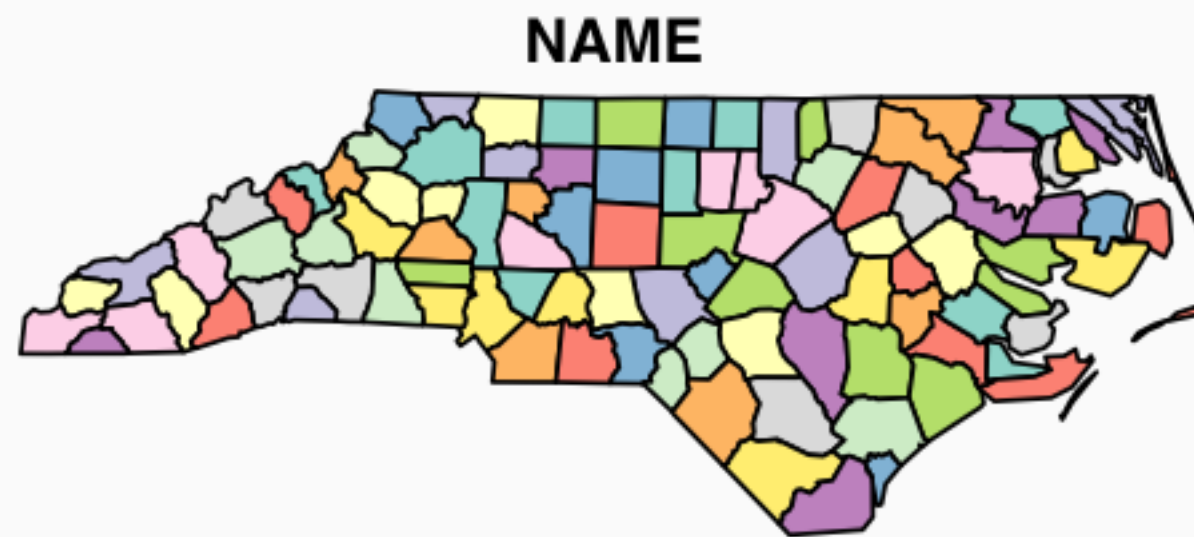
Example Data - NC SIDS

```
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...
```

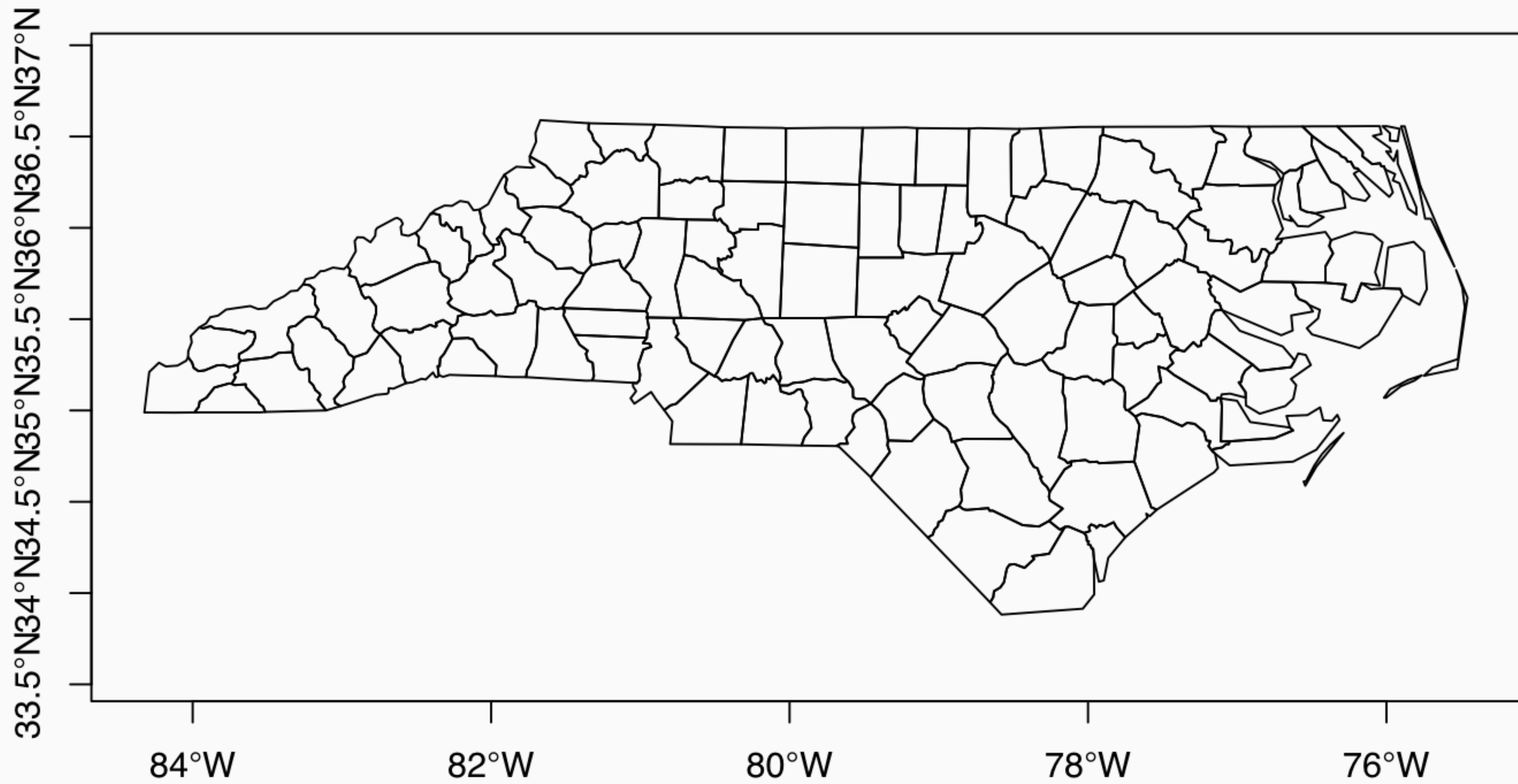

Base Plots

`plot(nc)`



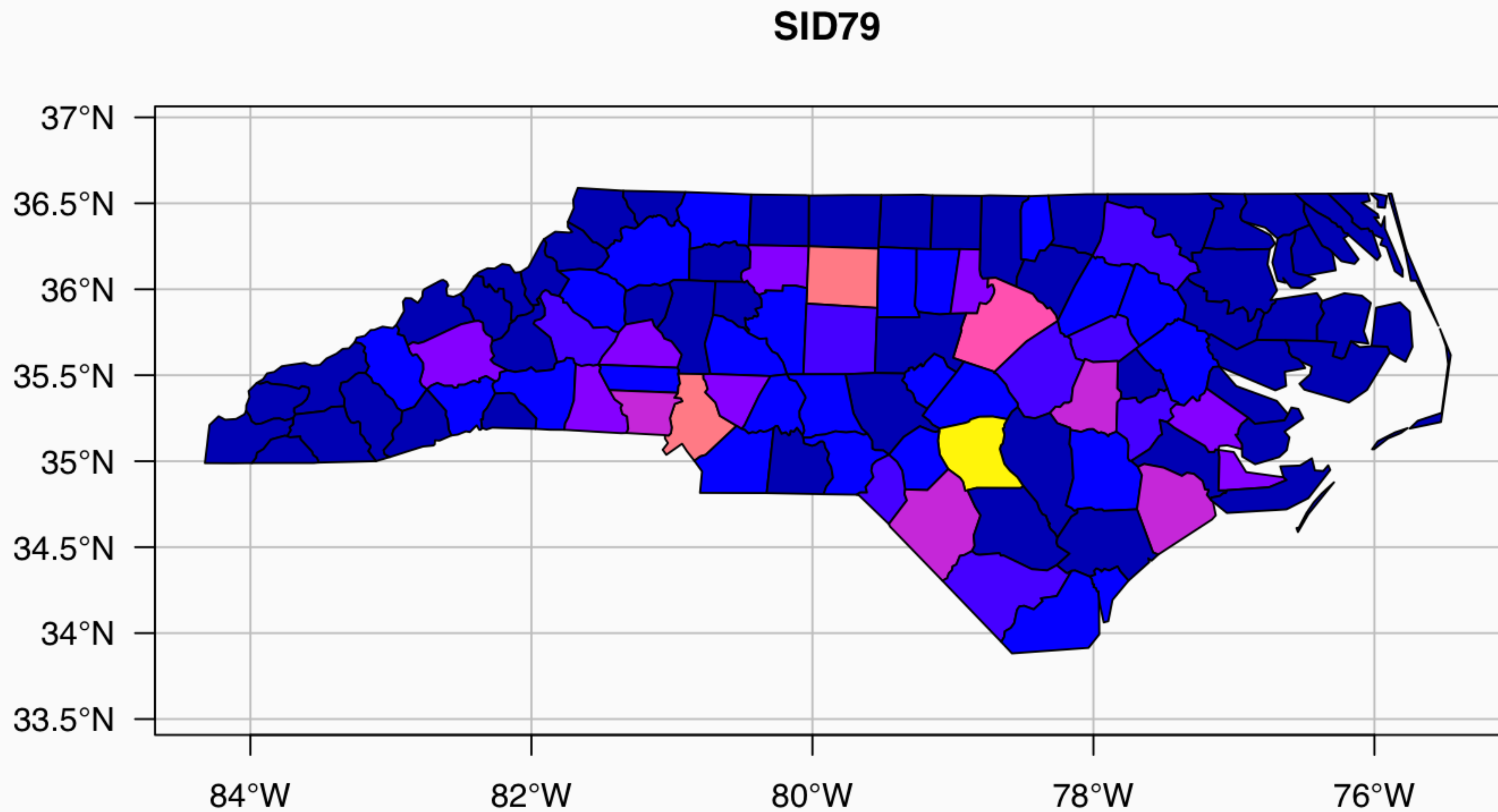
Geometry Plot

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



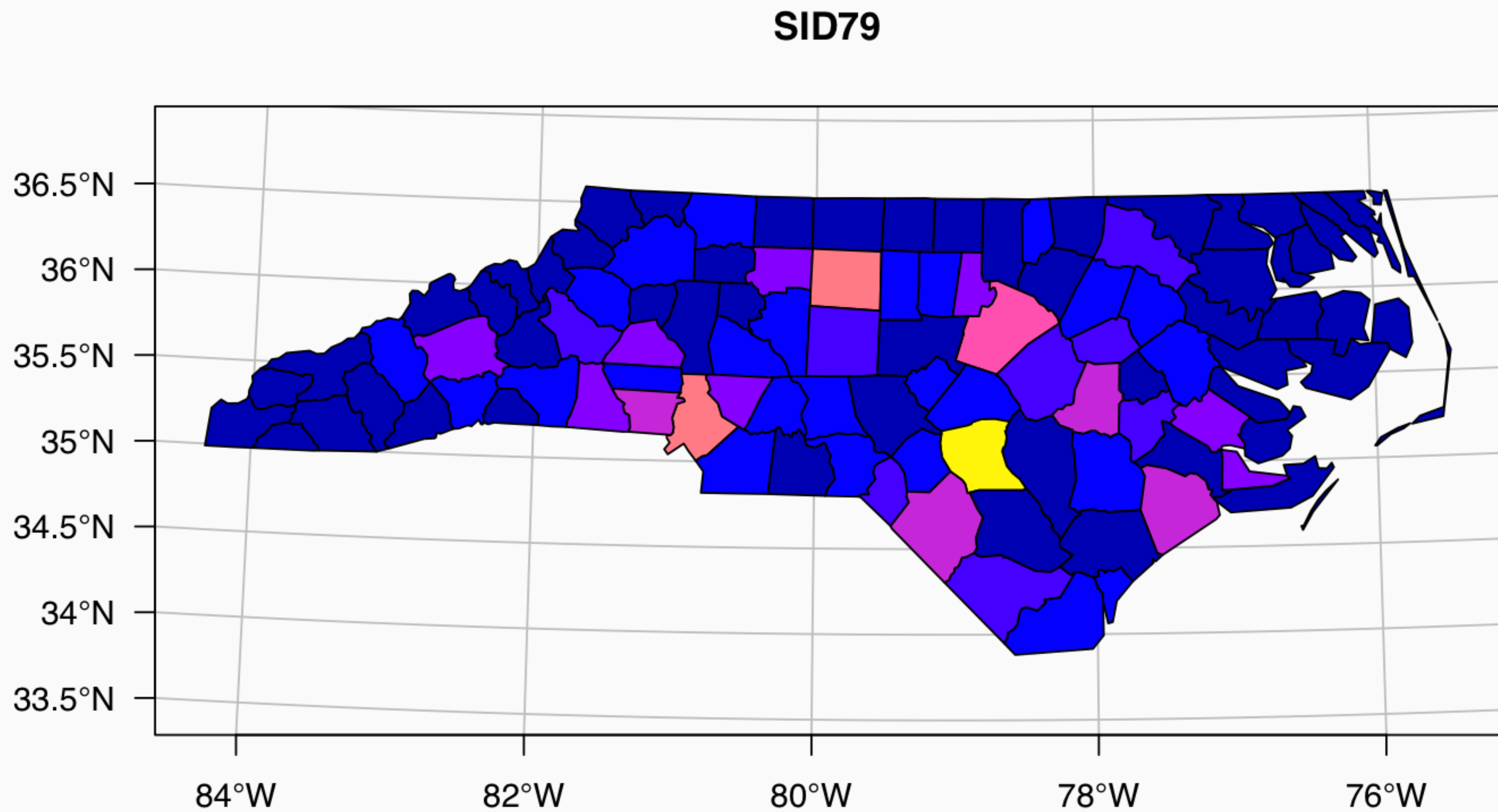
Graticules

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

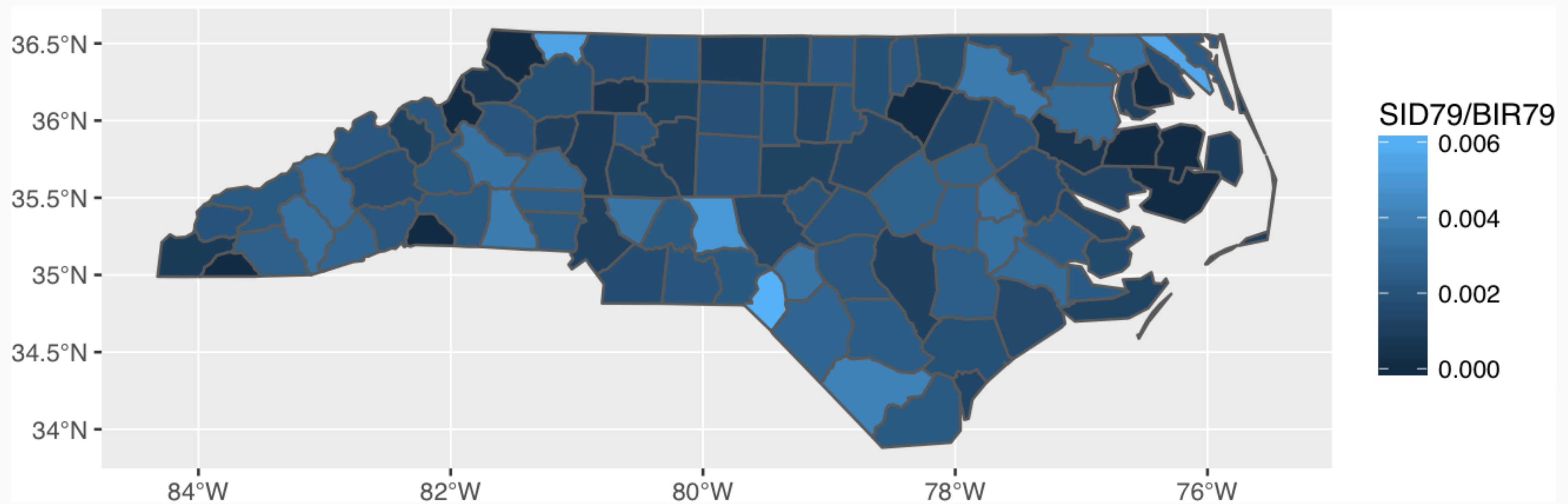


Graticules (EPSG:3631)

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

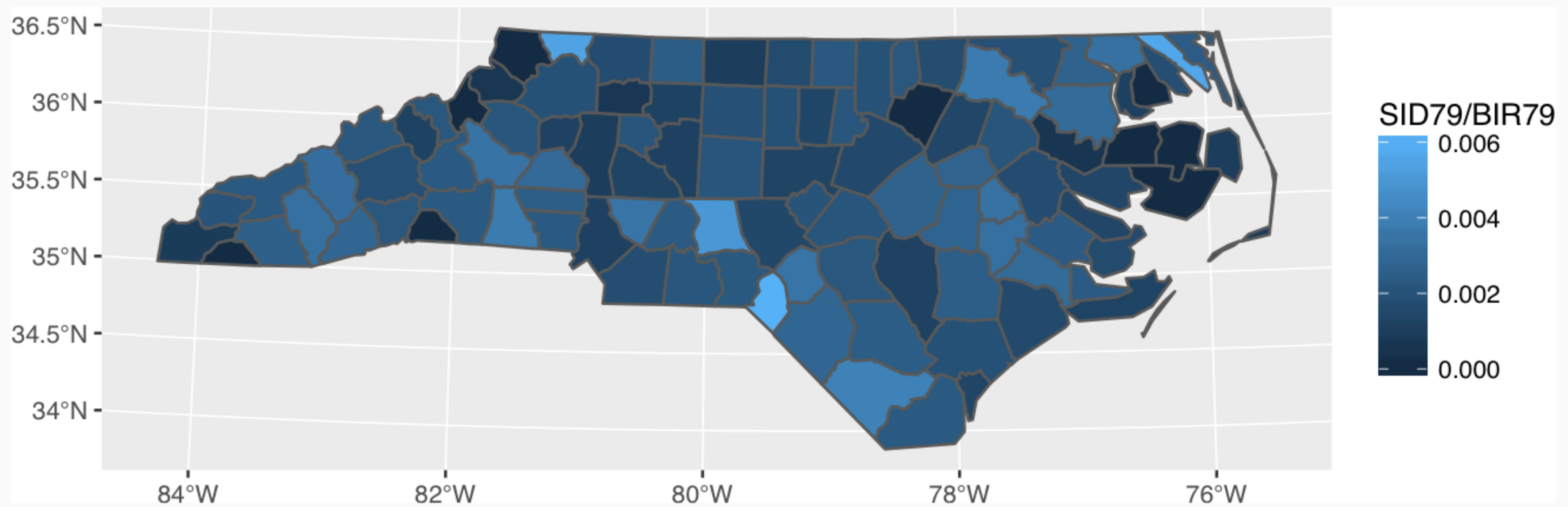



```
ggplot(nc) +  
  geom_sf(aes(fill=SID79 / BIR79))
```



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=5.387638888888889 +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
```

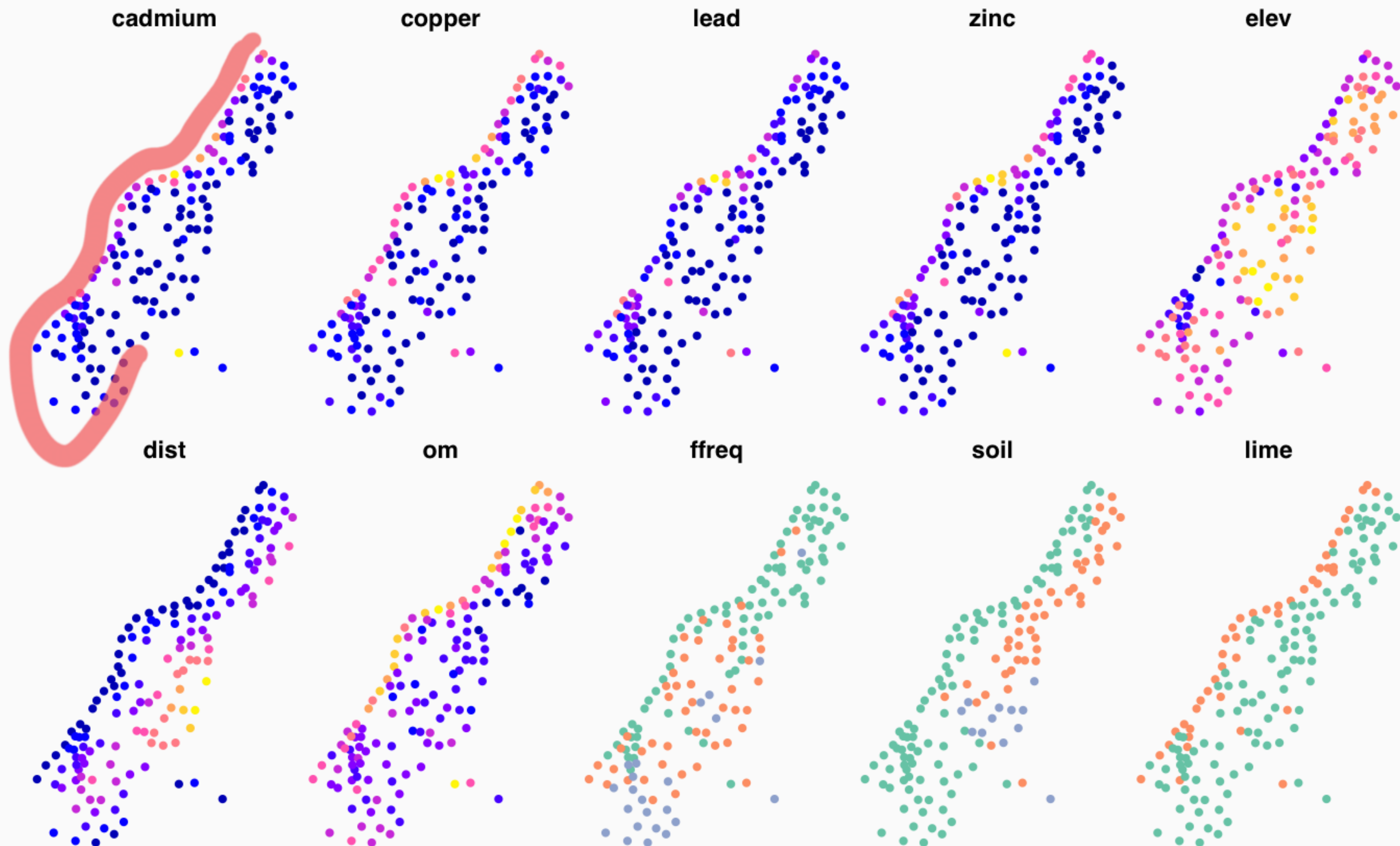
```
## 12      1.8      25   97  251 9.073 0.22812300  9.0      1      1      0
```

```
## 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
```

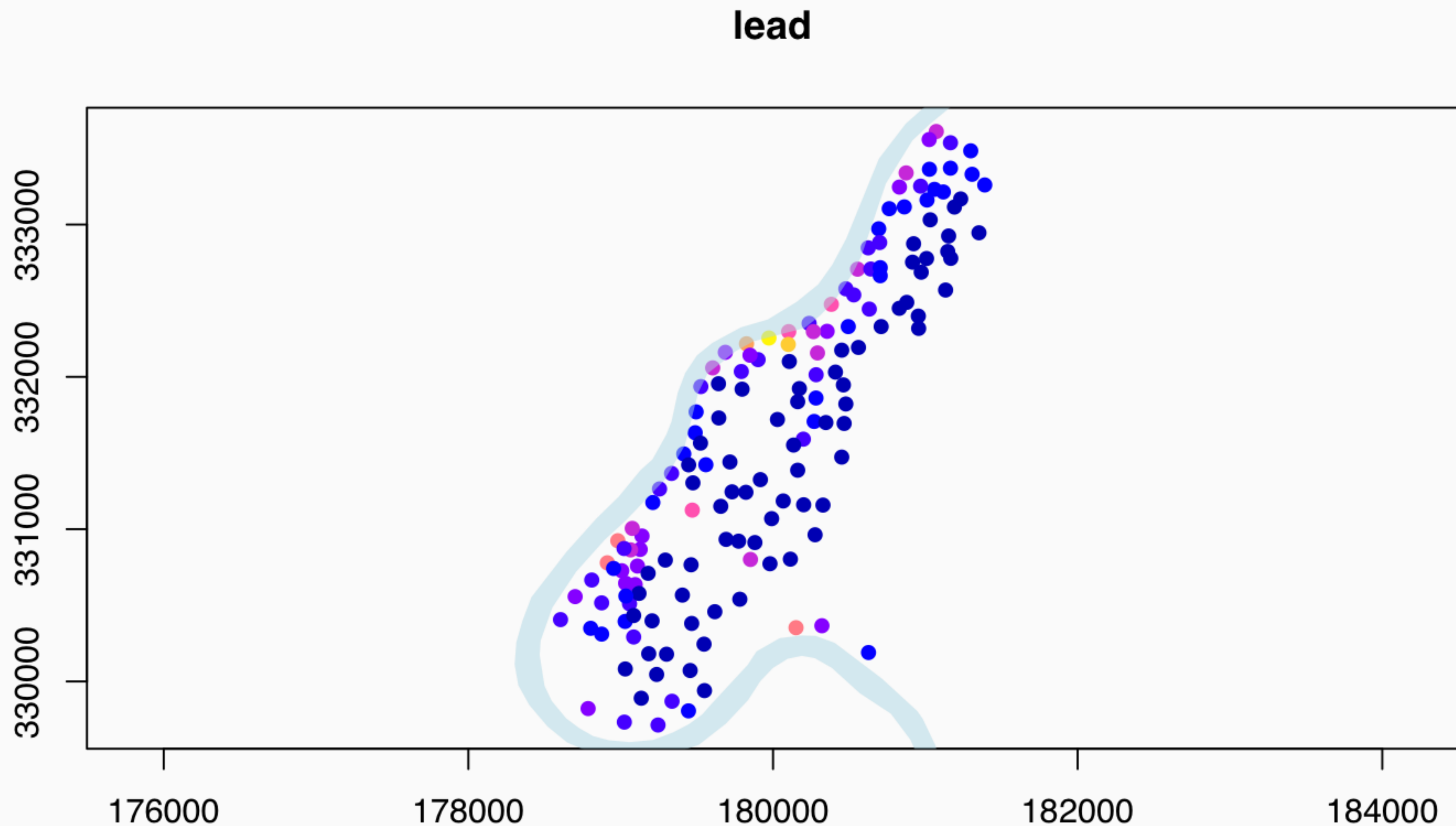

Meuse

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



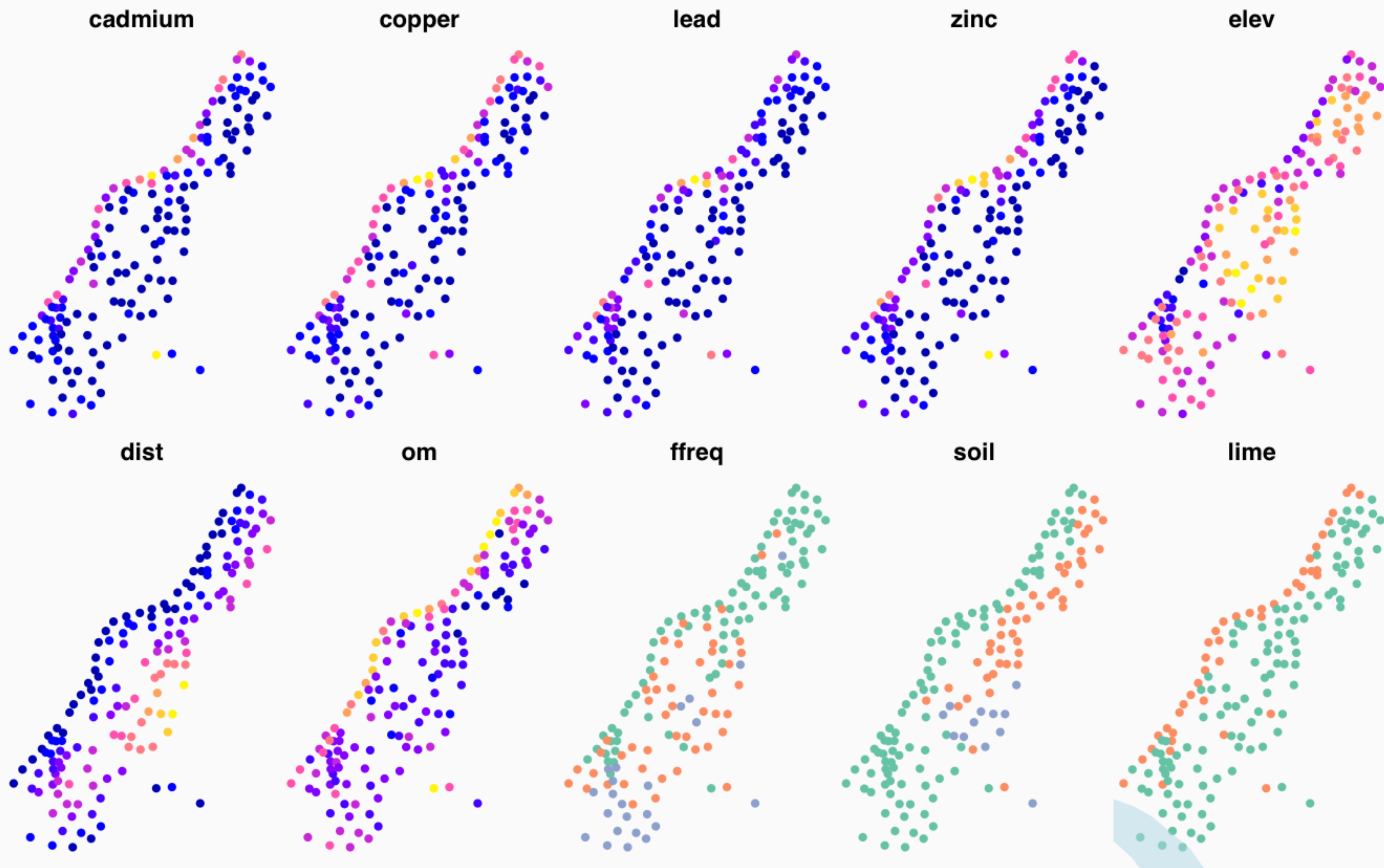
Layering plots

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

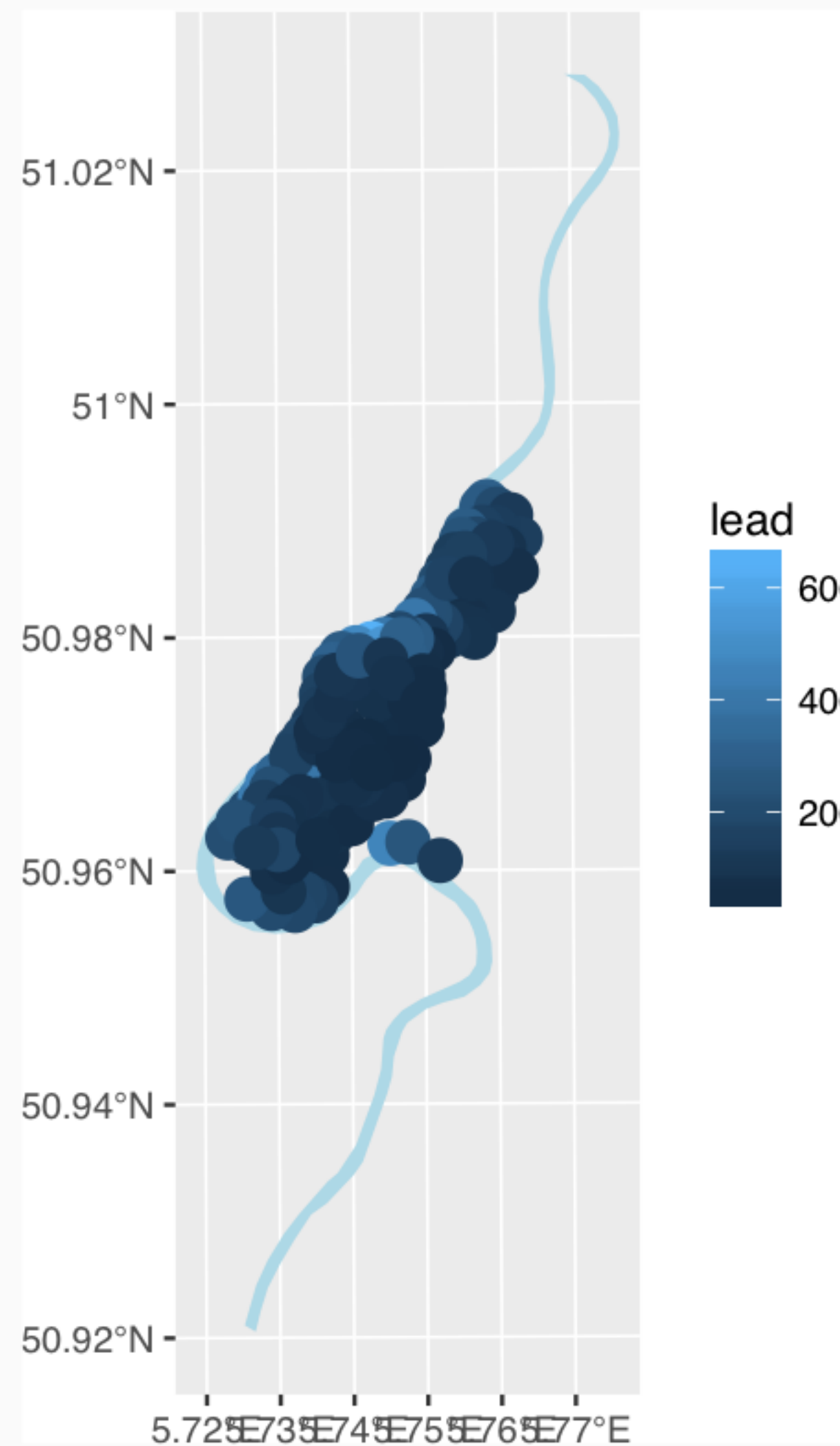


Layering plots (oops)

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

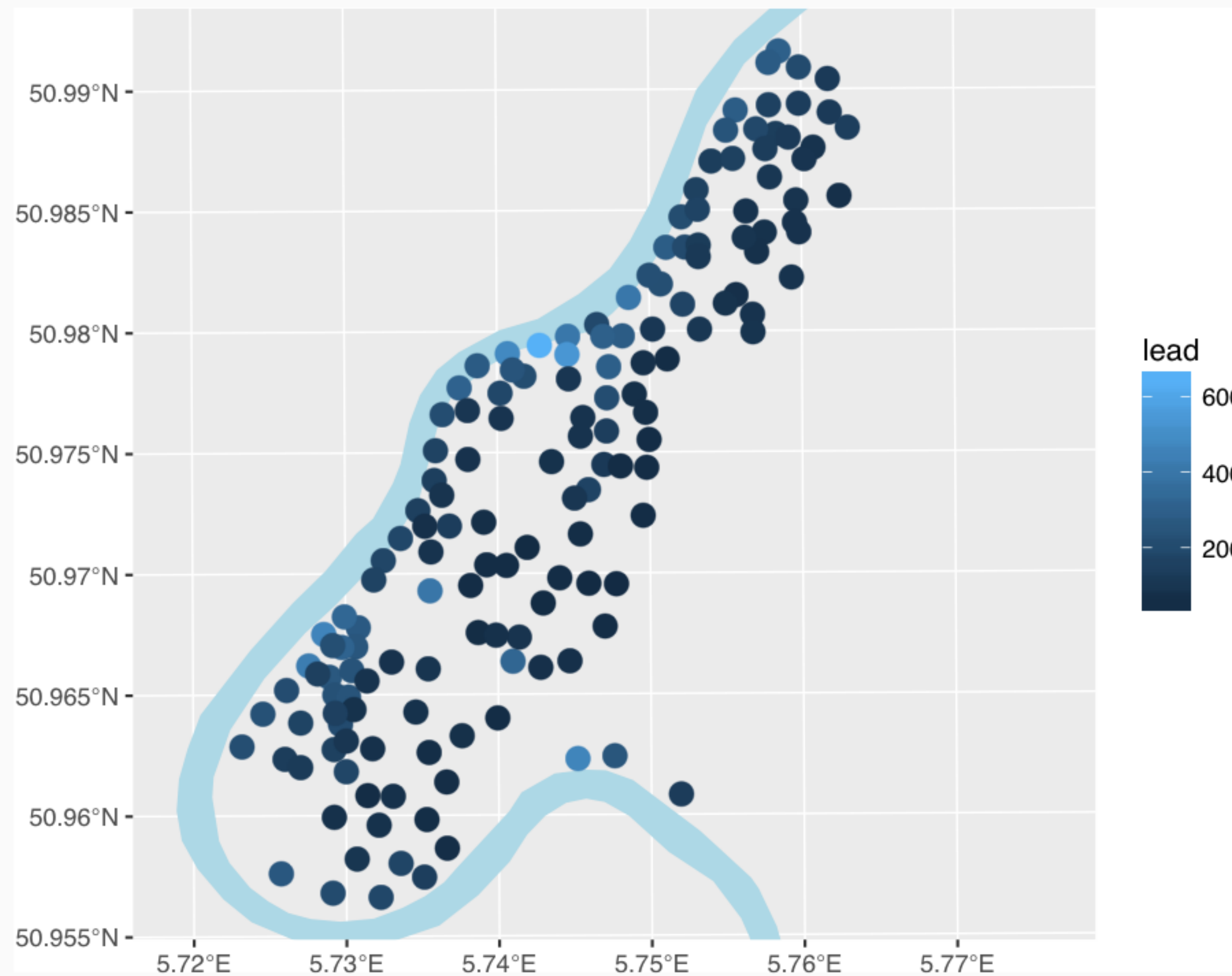


```
ggplot() +  
  geom_sf(data=st_sf(meuse_riv), fill="lightblue", color=NA) +  
  geom_sf(data=meuse, aes(color=lead), size=1)
```



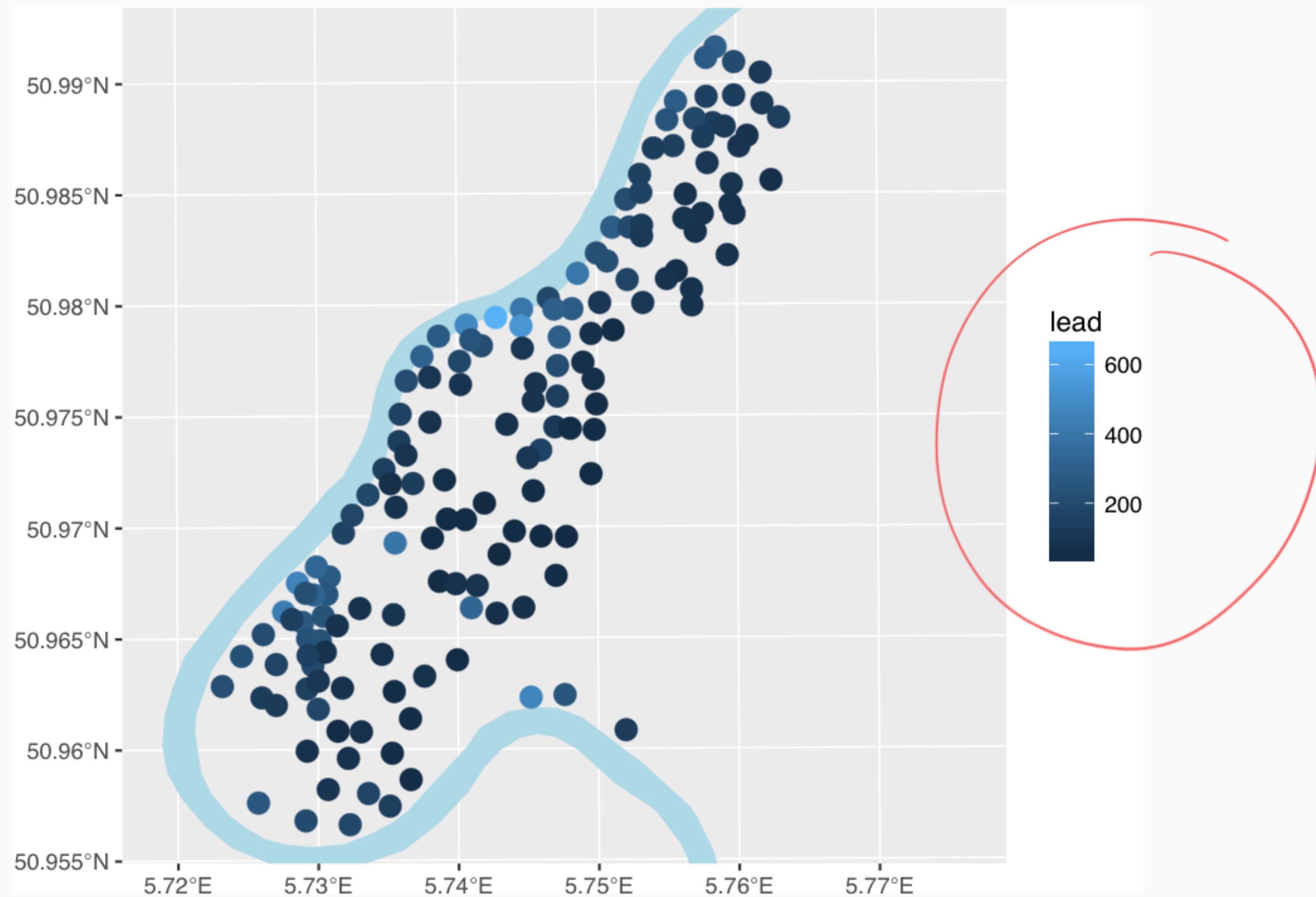
ggplot2 - axis limits

```
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
```

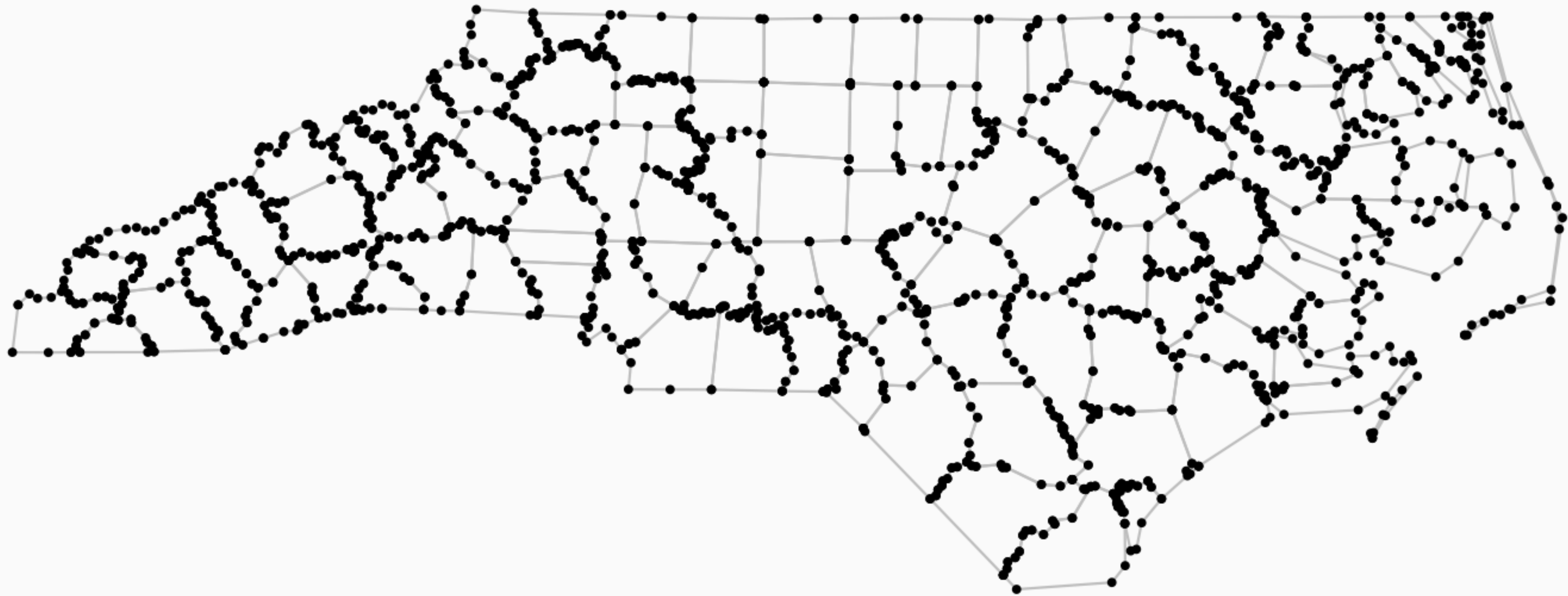
```
## epsg (SRID): 4267
```

```
## 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
```

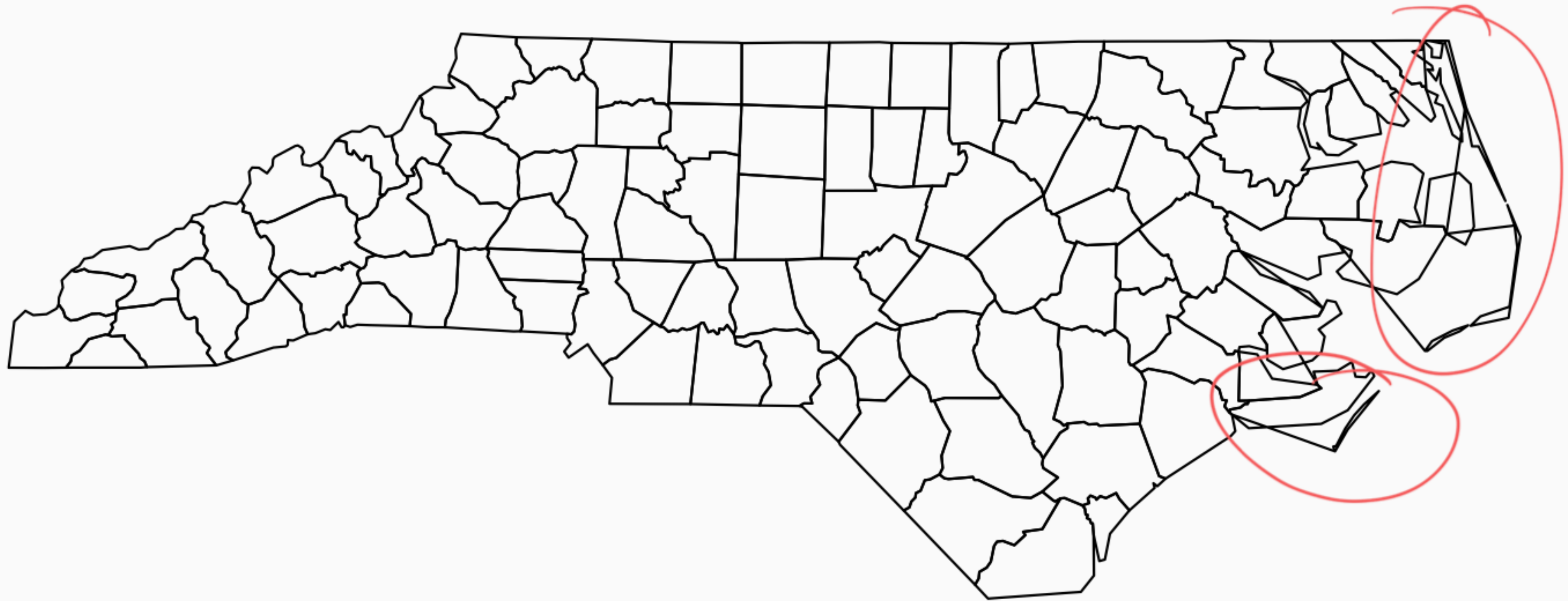
```
## proj4string:     +proj=longlat +datum=NAD27 +no_defs
```

```
## 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

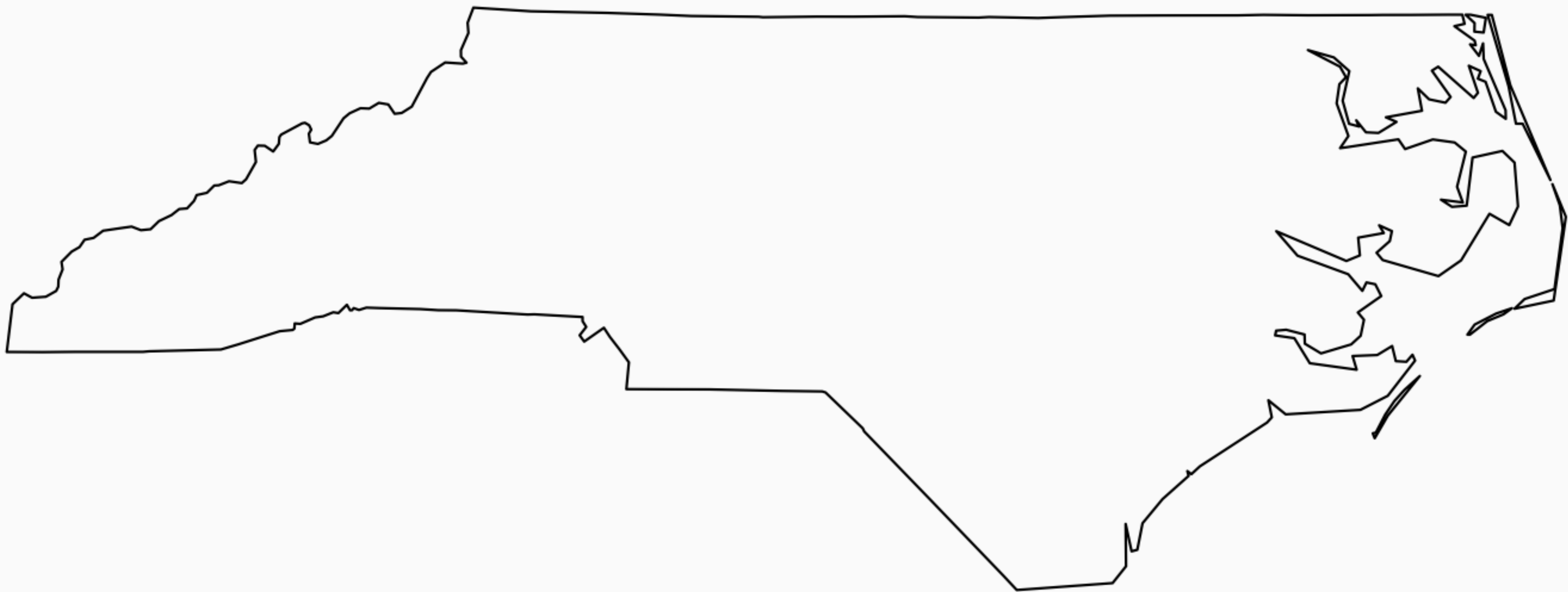



```
st_cast(nc, "LINESTRING") %>% st_geometry() %>% plot()
```



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
```

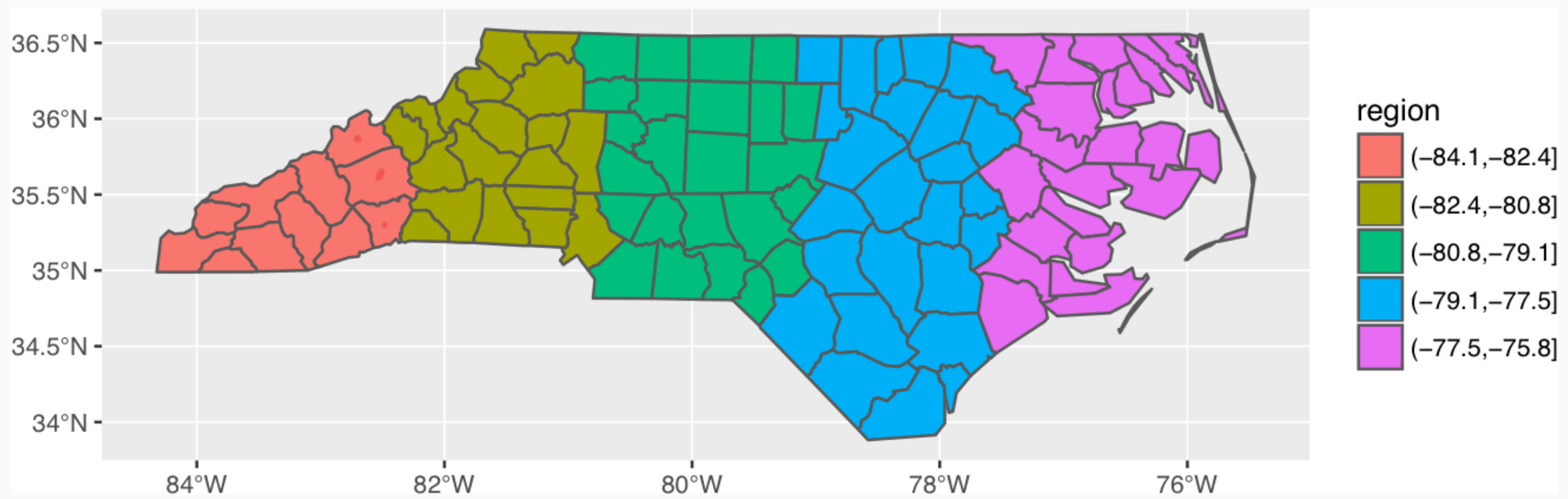

More Grouping

```
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
```

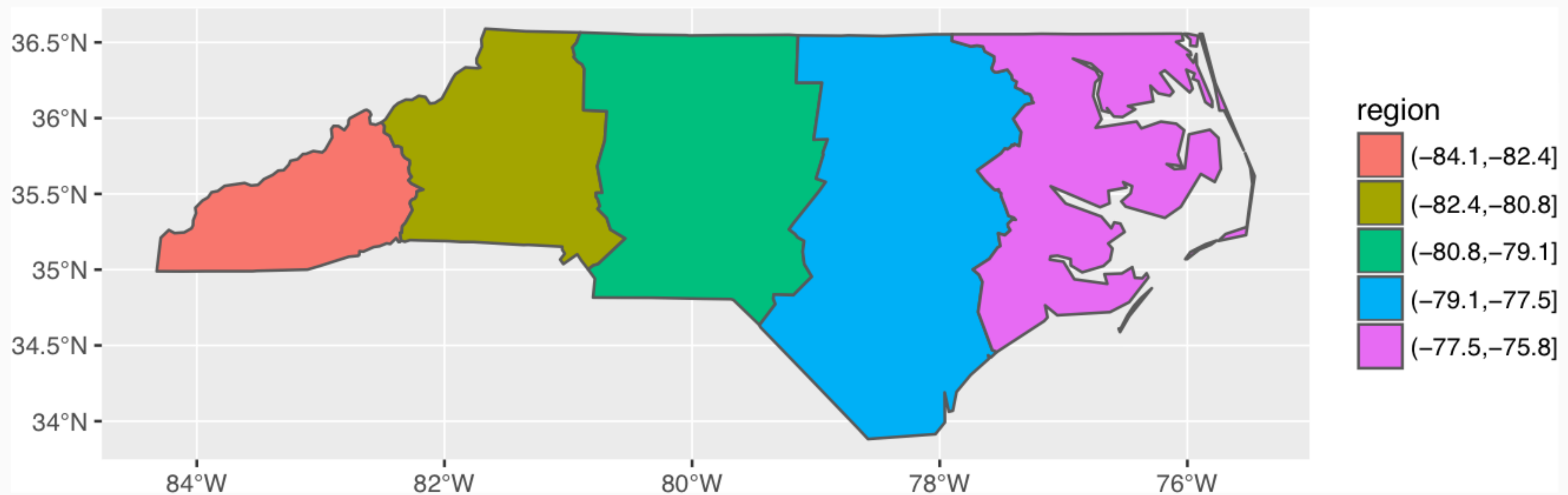


```
ggplot(nc_cut) +  
  geom_sf(aes(fill=region))
```



dplyr and sf - BFFs

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



Affine Transformations

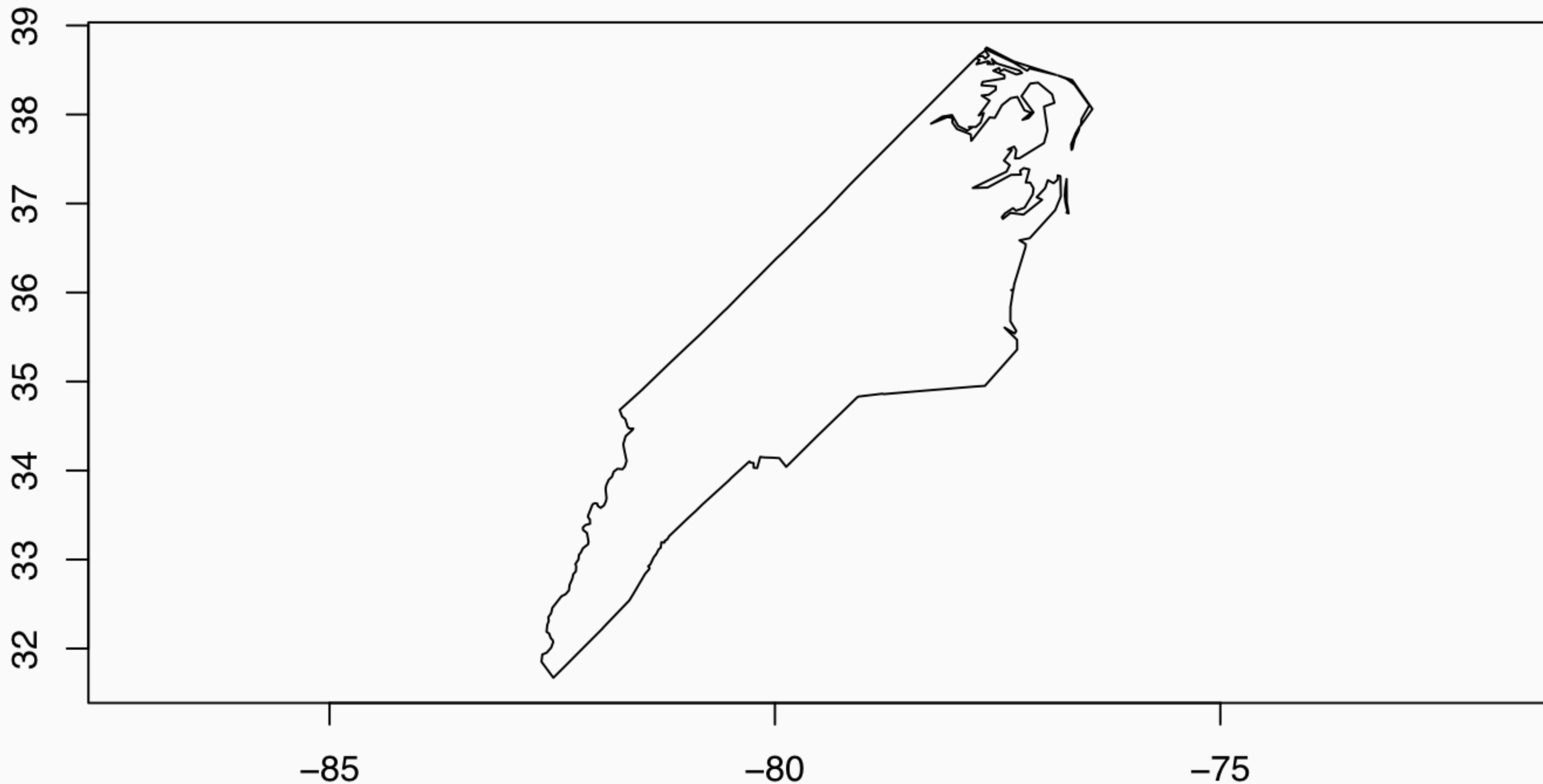
```
rotate = function(a) matrix(c(cos(a), sin(a), -sin(a), cos(a)), 2, 2)
```

```
ctrd = st_centroid(nc_state)
```

```
state_rotate = (nc_state - ctrd) * rotate(-pi/4) + ctrd
```

```
plot(state_rotate, axes=TRUE)
```

$$y = Ax + b$$

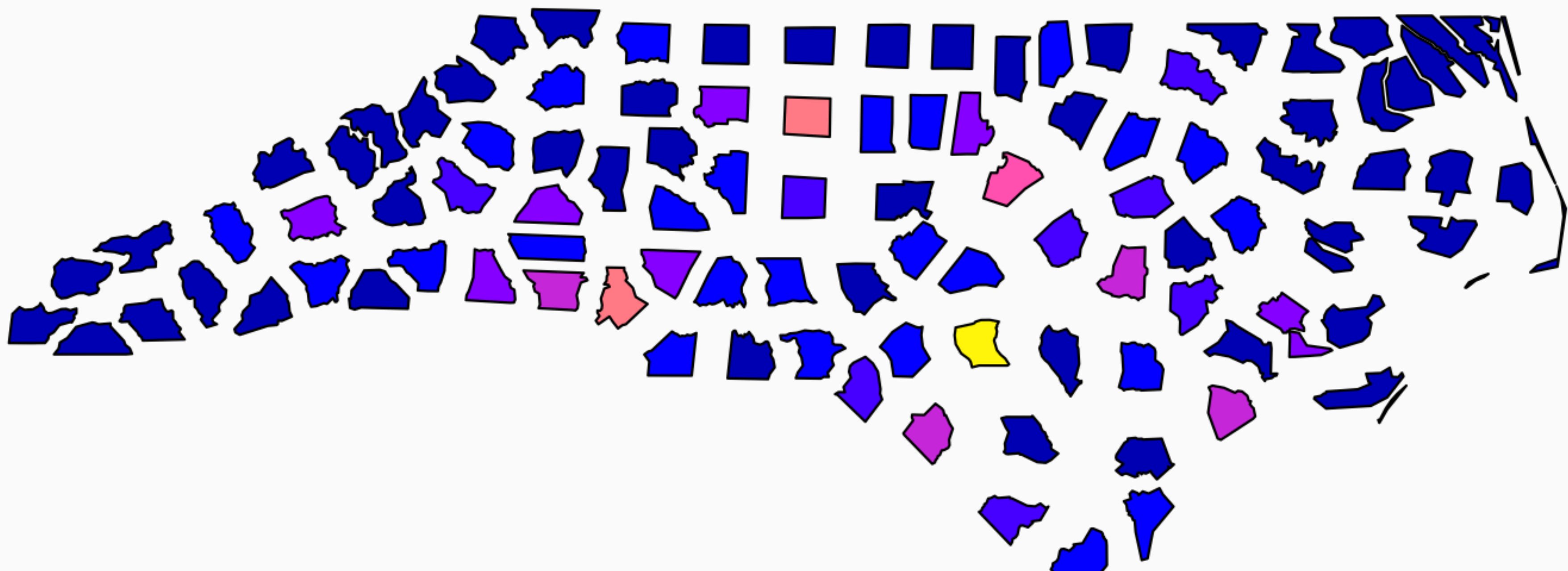


Scaling Size

```
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"])
```

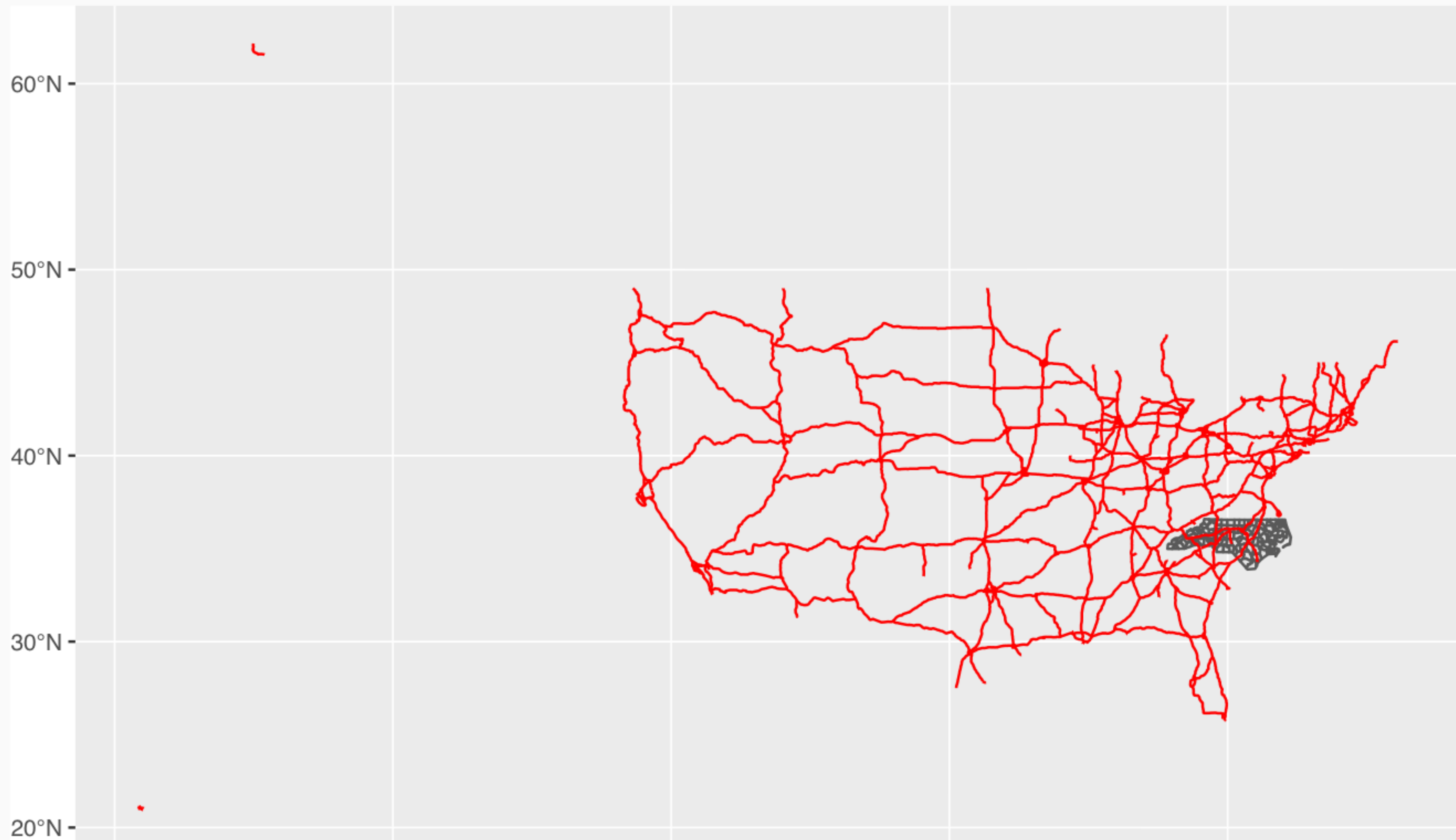
SID79



Back to the highways

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

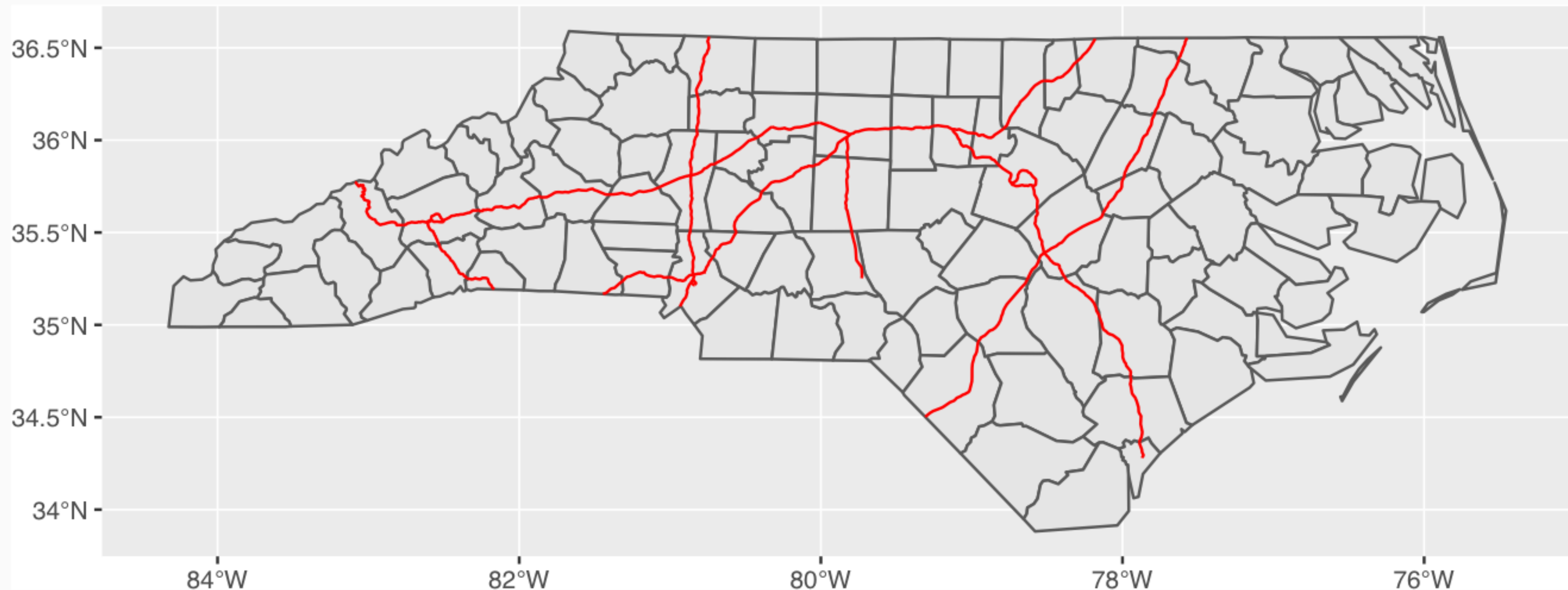
```
ggplot() +  
  geom_sf(data=nc) +  
  geom_sf(data=hwy, col='red')
```



NC Interstate Highways

```
hwy_nc = st_intersection(hwy, nc)
```

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



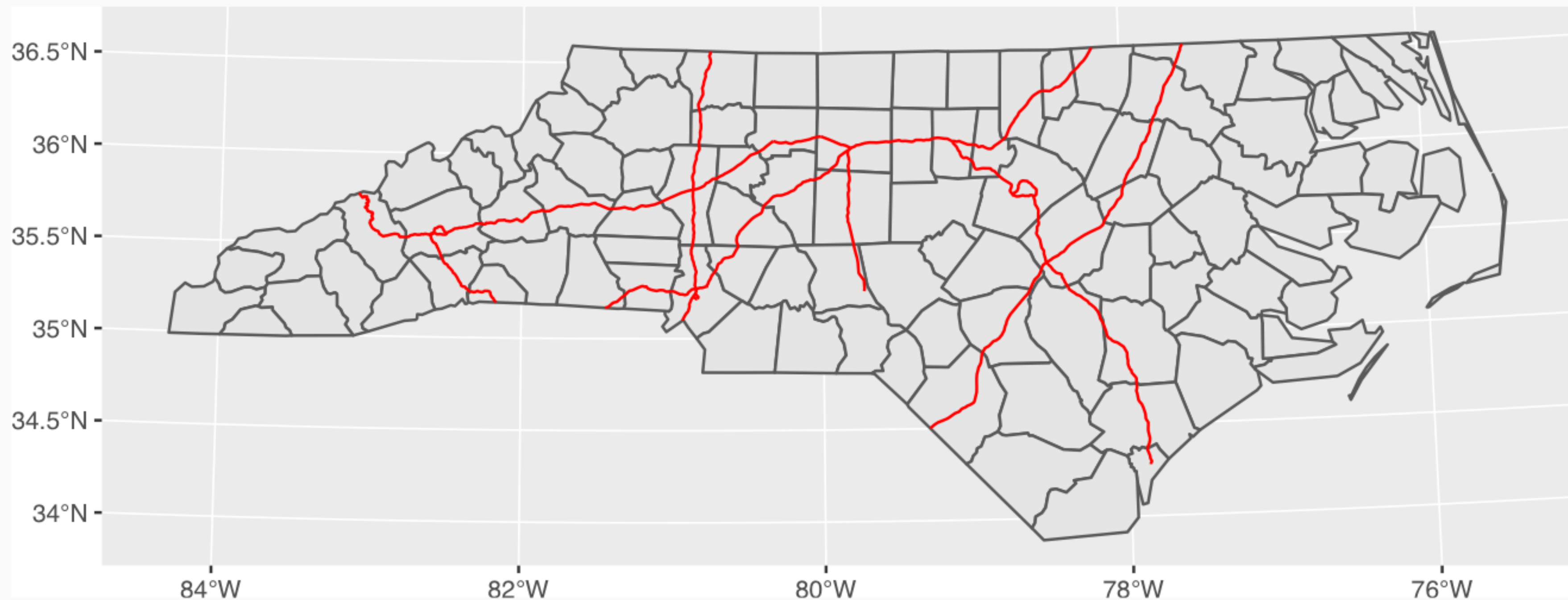
```
hwy_nc  
## Simple feature collection with 56 features and 10 fields  
## geometry type:  GEOMETRY  
## dimension:      XY  
## bbox:           xmin: -83.09008 ymin: 34.2791 xmax: -77.57348 ymax: 36.56092
```


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)
```

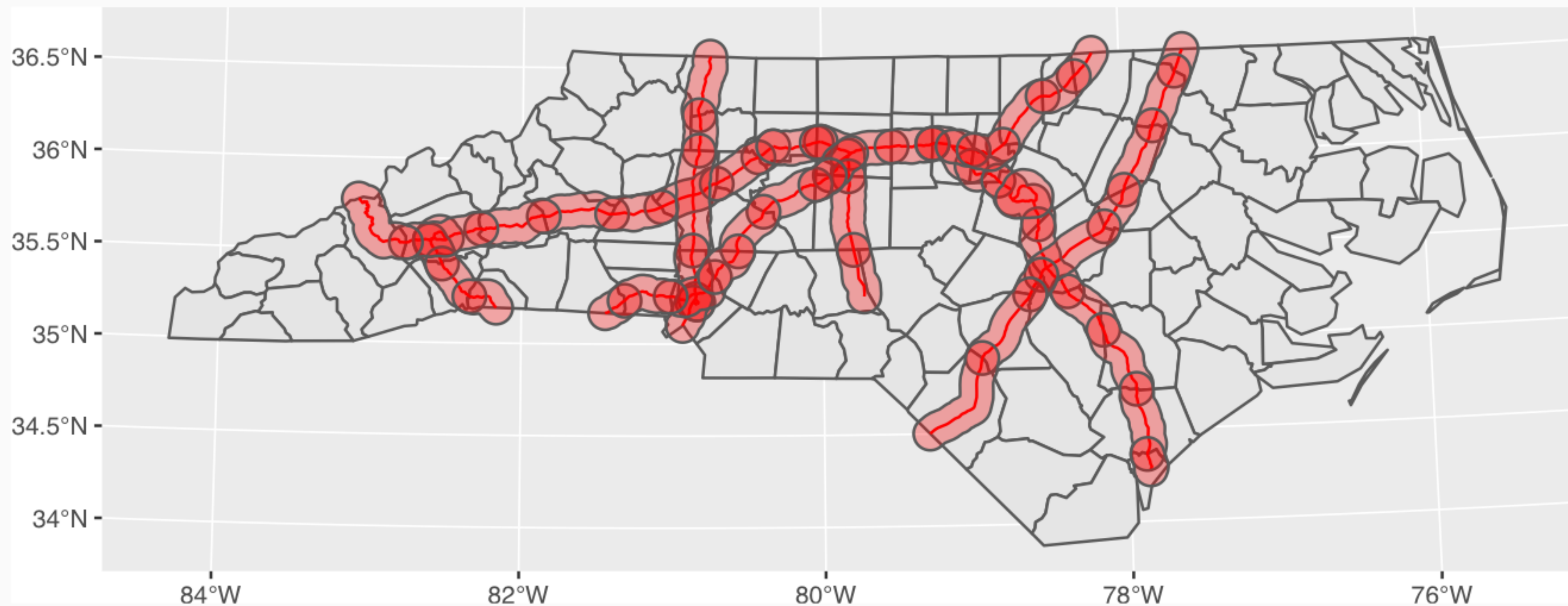
```
ggplot() +  
  geom_sf(data=nc_utm) +  
  geom_sf(data=hwy_nc_utm, col='red')
```



Counties near the interstate (Buffering)

```
hwy_nc_buffer = st_buffer(hwy_nc_utm, 10000)
```

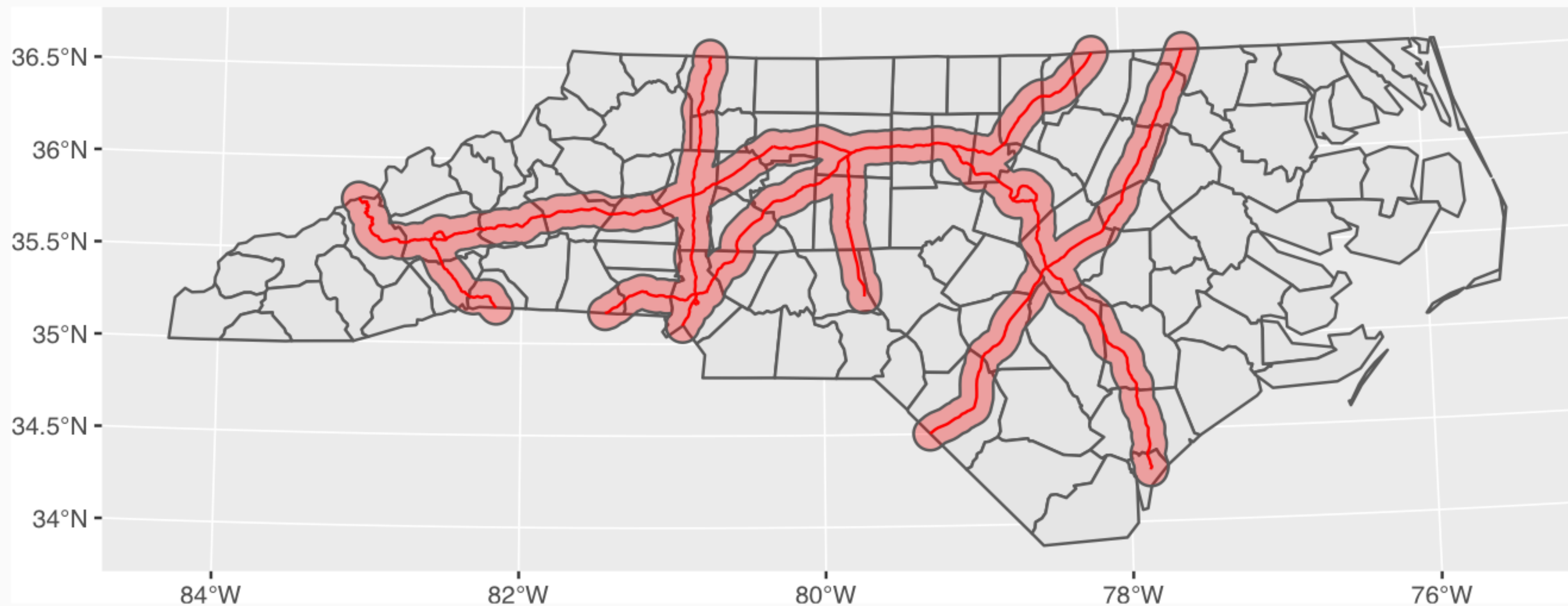
```
ggplot() +  
  geom_sf(data=nc_utm) +  
  geom_sf(data=hwy_nc_utm, color='red') +  
  geom_sf(data=hwy_nc_buffer, fill='red', alpha=0.3)
```



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,
```

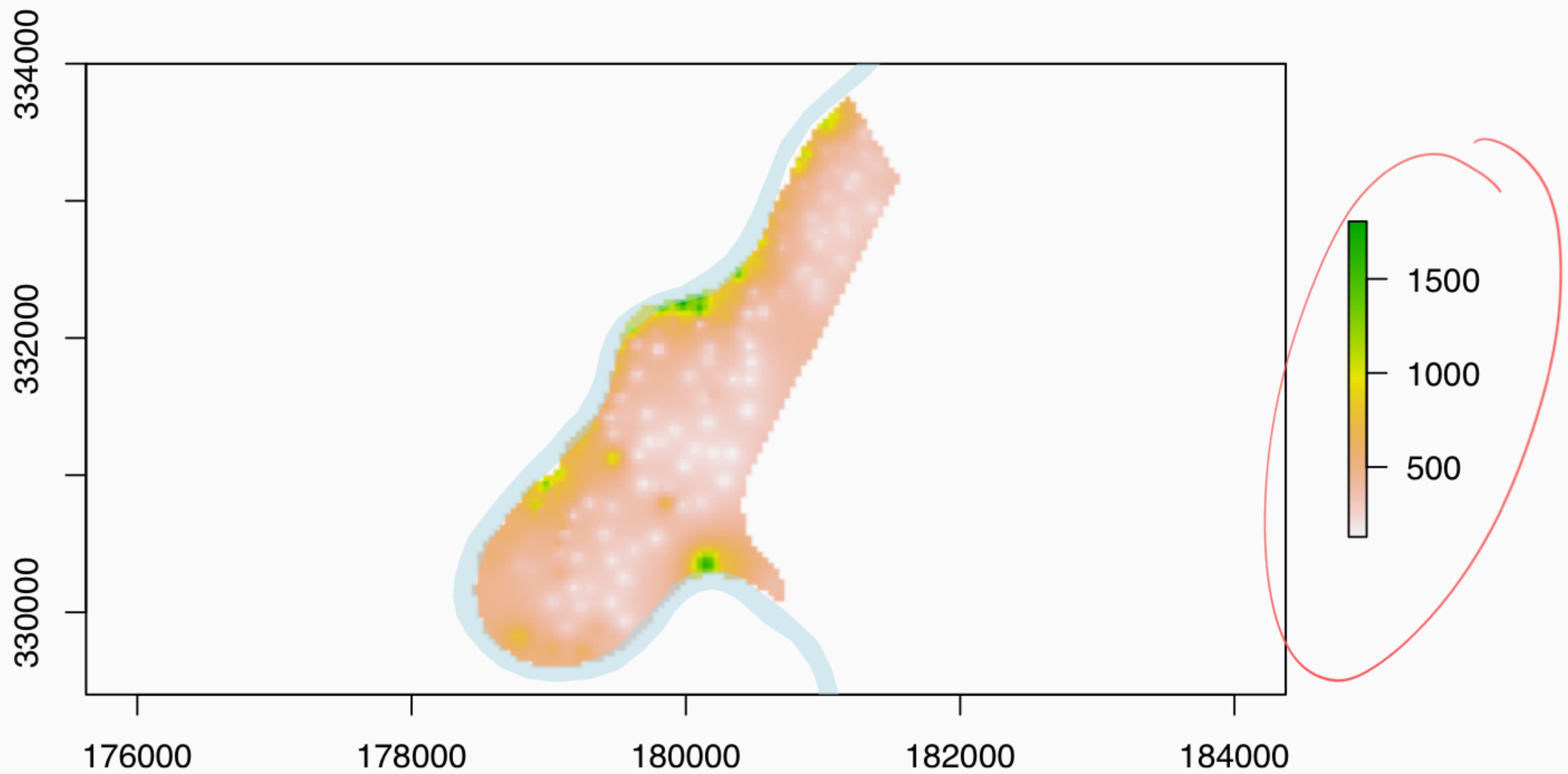
```
## data source : /usr/local/lib/R/3.3/site-library/raster/external/test.grd
```

```
## names       : test
```

```
## values      : 128.434, 1805.78 (min, max)
```



```
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,
```

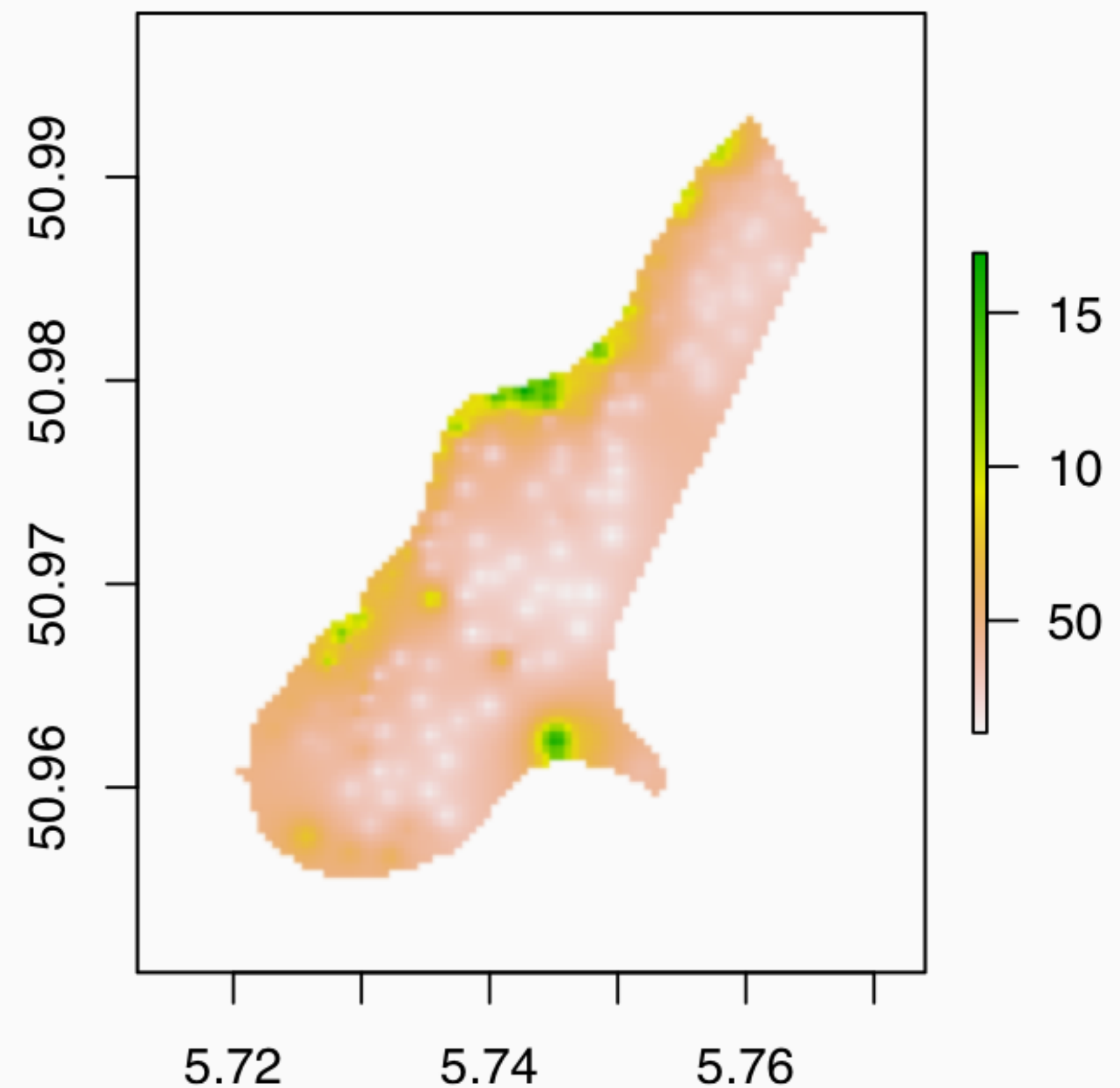
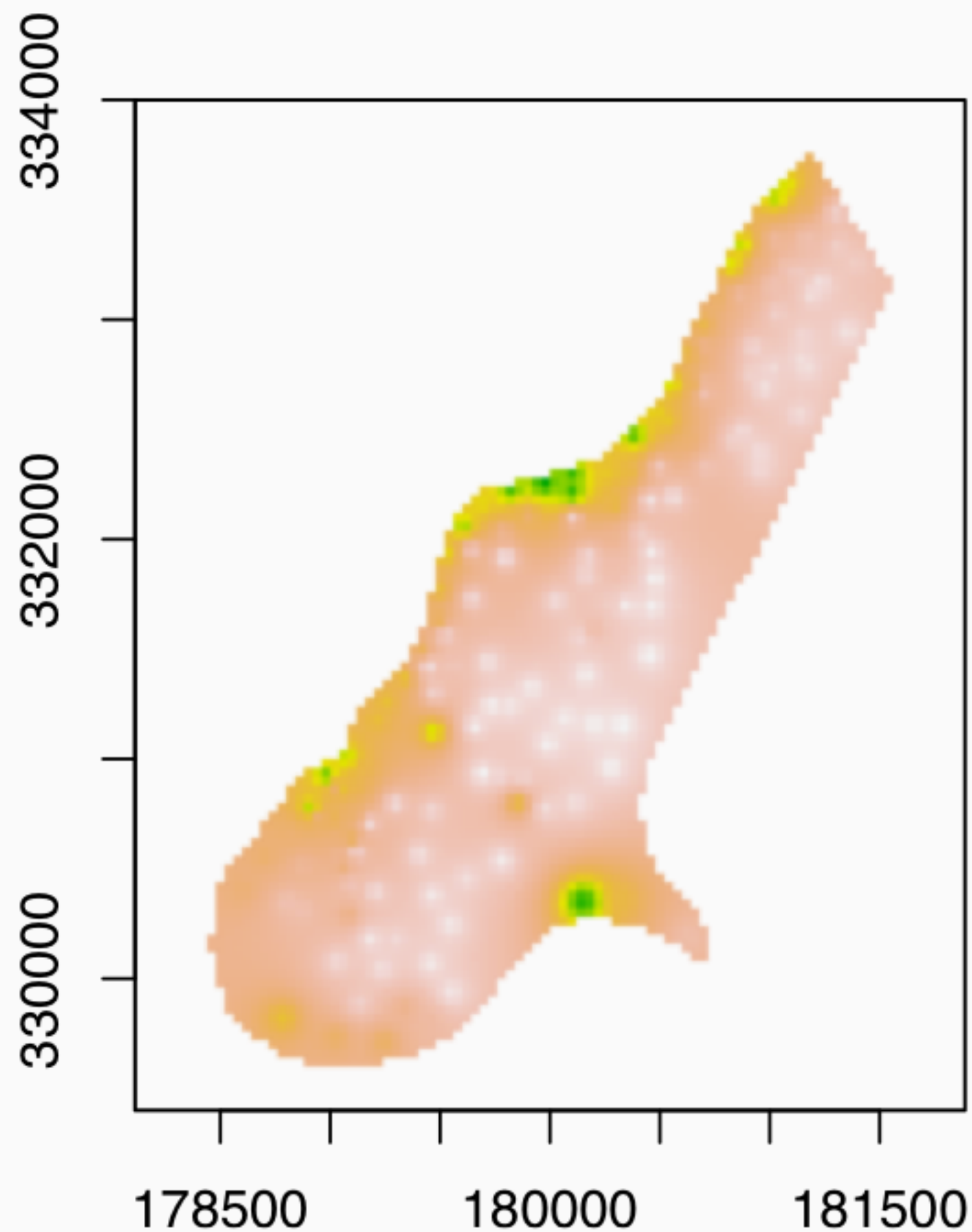
```
meuse_rast[20,]
```

```
## [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)
```



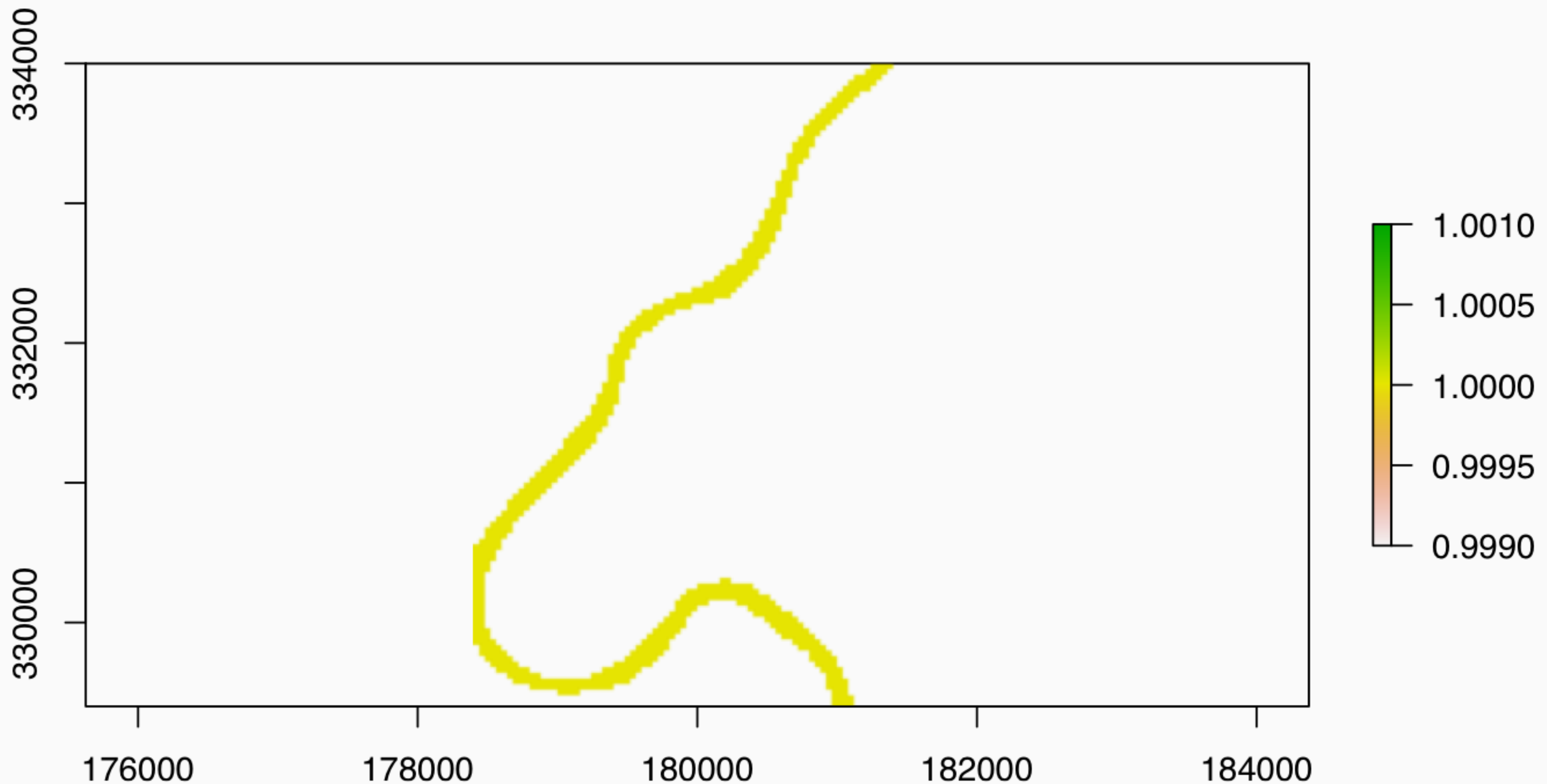
```
meuse_rast
## class      : RasterLayer
## dimensions : 115, 80, 9200  (nrow, ncol, ncell)
## resolution : 40, 40  (x, y)
## extent     : 178400, 181600, 329400, 334000  (xmin, xmax, ymin, ymax)
## coord. ref.: +init=epsg:28992 +towgs84=565.237,50.0087,465.658,-0.406857,0.350733,
## data source : /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 $\longleftrightarrow$ Rasters

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

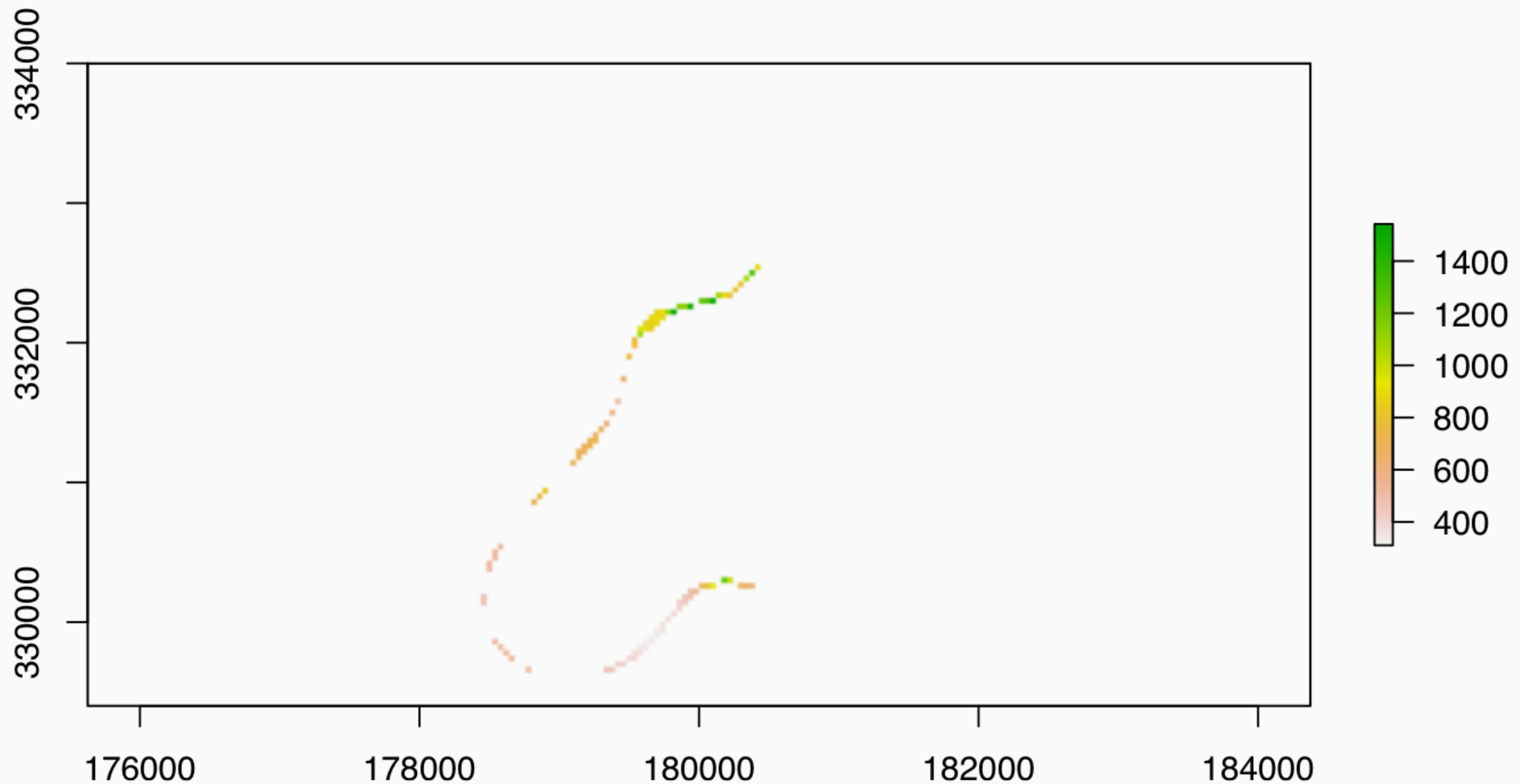
meuse_riv_rast = rasterize(as(meuse_riv, "Spatial"), meuse_rast)
plot(meuse_riv_rast)
```




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

```
river_obs = meuse_rast  
river_obs[!sub] = NA
```

```
plot(river_obs)
```



```
xyFromCell(river_obs, which(sub))
```

```
##           x           y
```

```
## [1, ] 180420 332540
```

Rasters and Spatial Models

```
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=5.387638888888889 +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))
```

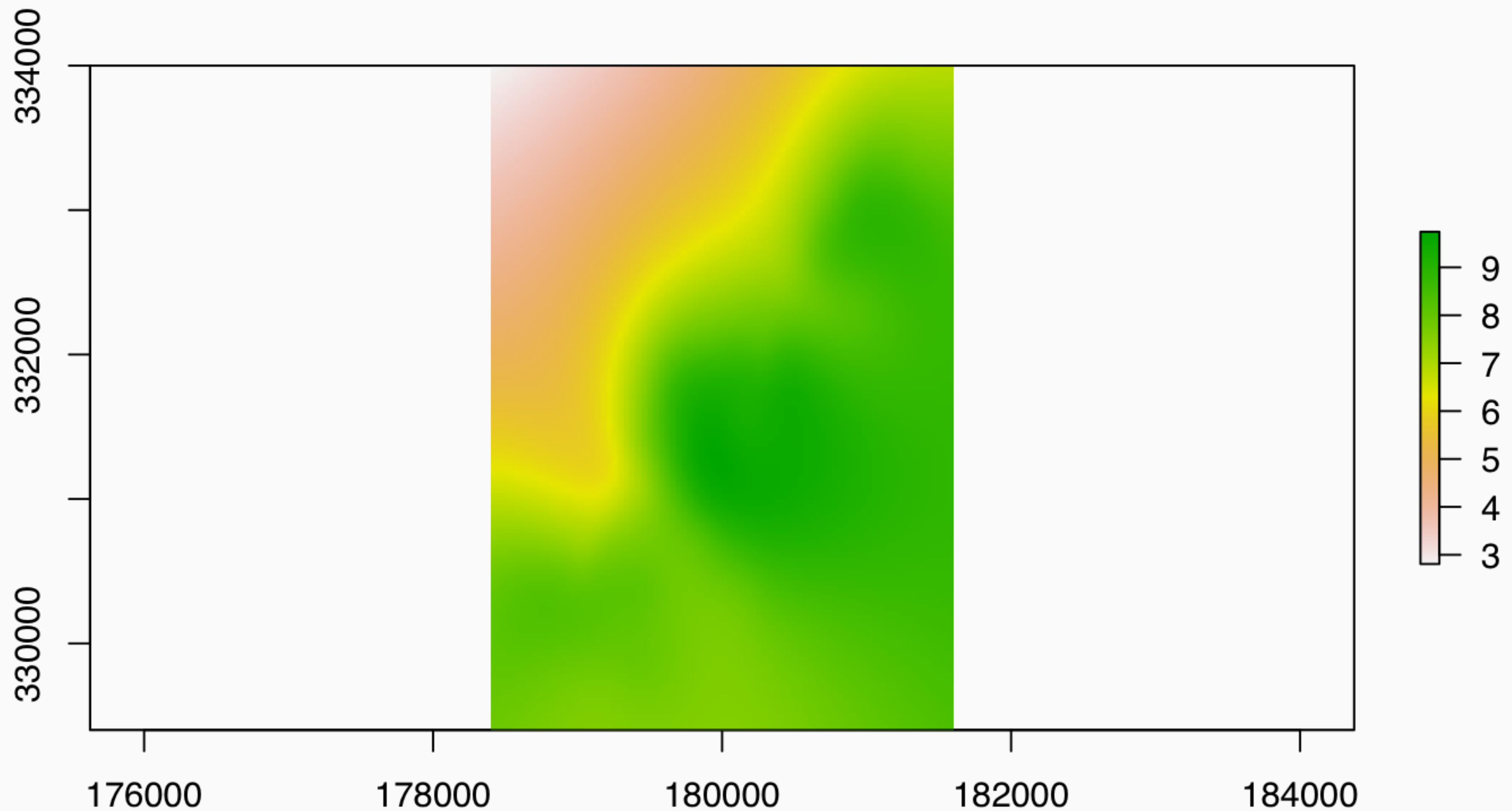
```
##           X           Y
## 1 181072 333611
## 2 181025 333558
## 3 181165 333537
```

```
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  
)
```

