WORKSHOP | Spatial Analysis in R

TxGIS Day 2021

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Nov 16, 2021, 2:30 PM - 3:45 PM

WORKSHOP | Spatial Analysis in R

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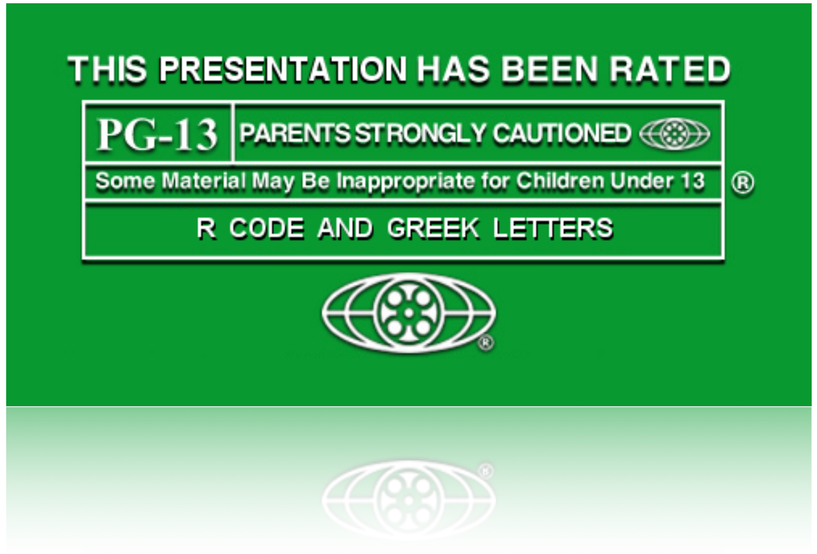
3. Spatial *vector* data
4. Mapping
5. Hands on “Walking, Cycling, and Driving Distances”
6. (Hands on “Elevation Analysis”)



About me

Alexander Abuabara

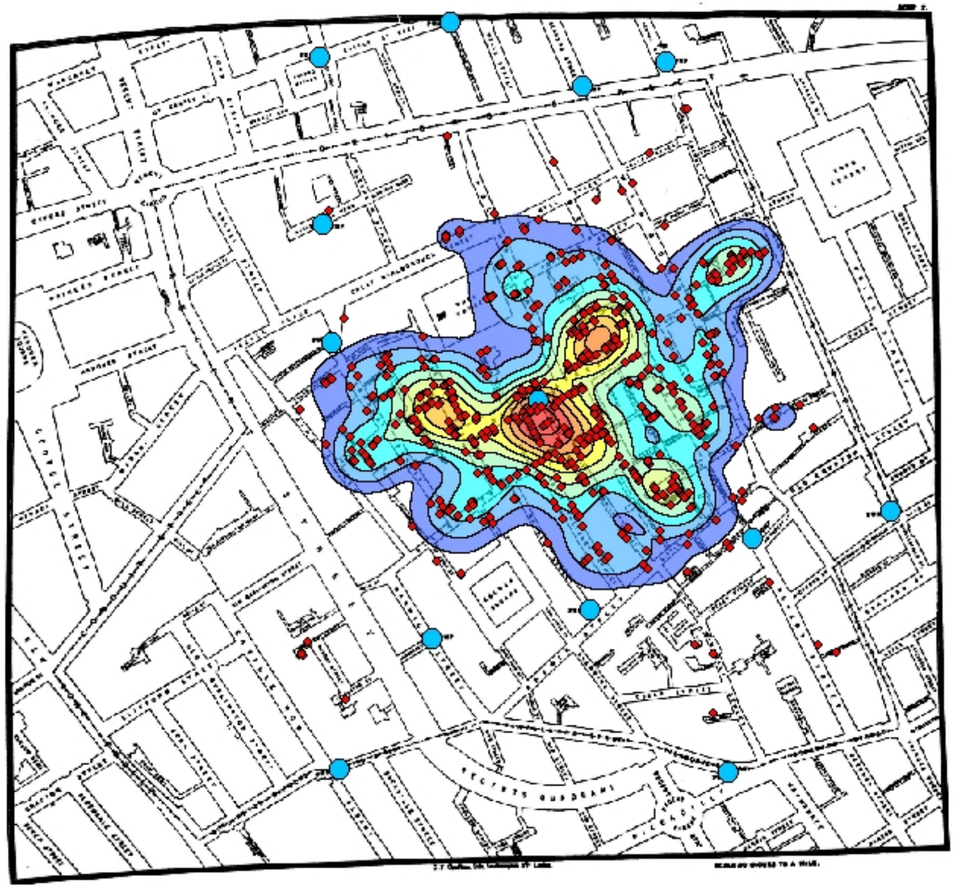
- Urban scientist and hazard researcher at Texas A&M University
- PhD candidate in Urban and Regional Science
- Research on hurricane risk on coastal communities using causal probabilistic analysis through influence diagrams (Bayesian networks), which includes mapping risk for a possible better risk communication
- Hurricane Evacuation Zones

Some assumptions

- You have R-4 and RStudio Desktop installed (free and available in most plataforms)
- Basic GIS and spatial language
- Some understanding of how R works, setup a working folder, execute a code, save files
  (basic manuals https://cran.r-project.org)

Uses of spatial data in science

- using location or spatial relationships as an **explanatory** or **predictive** variable
- examining the effects of **scale**
- backdrops to show **context**

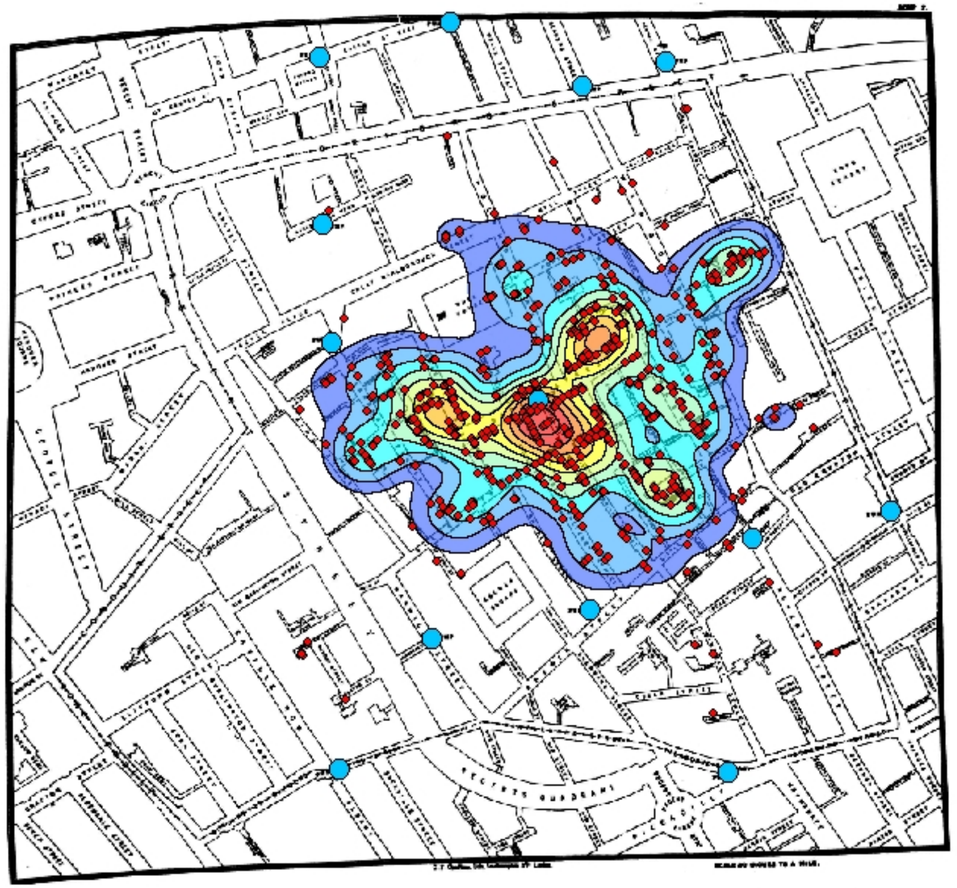


Picture from Andy Lyons
The Berkeley R Language Beginner Study Group

Challenges with spatial data in R

- Many types and **formats** of spatial data
- R is not the easiest program to learn
- There are a ton of **packages** from a very diverse user community

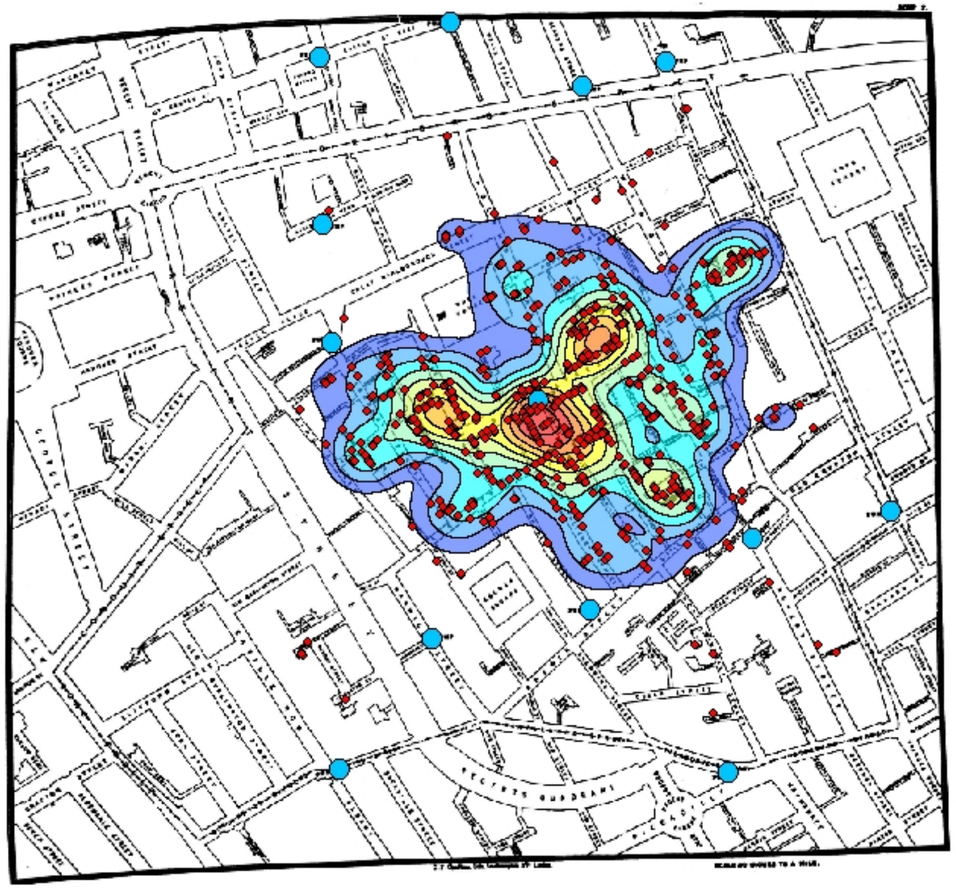
Understanding and manipulating spatial data in R can be a real challenge!



Picture from Andy Lyons
The Berkeley R Language Beginner Study Group

Presentation goals

- Point out some of the commonly-used packages for spatial data manipulation and analysis
- Help you get to the point where you can do an analysis or visualization
- Be a resource you can come back to



Picture from Andy Lyons
The Berkeley R Language Beginner Study Group

Getting started

Why R?

Attribute	Desktop GIS (Graphical User Interface)	Geocomputation with R
Home disciplines	Geography	Computing, Statistics
Software focus	Graphical User Interface	Command line
Reproducibility	Minimal	Maximal

- Community
- open source modeling tools
- R code run as fast as C (but a “higher” level language)
- Why R? 2020 Keynotes

Getting started

Why R?

- R is a free software environment for statistical computing and graphics.
- It compiles and runs on a wide variety of UNIX platforms, Windows and MacOS.
- Get familiar ... R as a calculator some basic R operators

Arithmetic operators

Operator	Description
+	Addition
-	Subtraction
*	Multiplication
/	Division
^ or **	Exponentiation

Logical operators

Operator	Description
<	Less than
<=	Less than or equal to
>	Greater than
>=	Greater than or equal to
==	Exactly equal to
!=	Not equal to
!x	Not x
x | y	x OR y
x & y	x AND y

Brief history of R-spatial

- Spatial packages already available in the **S** language since the 1990s (Bivand and Gebhardt, 2000)
- By 2000, modifications of these became R packages for point pattern analysis, geostatistics, exploratory spatial data analysis and spatial econometrics
- R-GIS bridges (Bivand, 2000)
- Bivand (2003) proposed a spatial data class system for R which eventually led to the packages **rgdal** (first released in 2003; Bivand, Keitt, and Rowlingson, 2018) and **sp** (first released in 2005; Bivand, Pebesma, and Gomez-Rubio, 2013)
- 2008: Applied Spatial Data Analysis with R (Bivand, Pebesma, and Gomez-Rubio, 2013)
- 2010: **raster** package (Hijmans, 2017)
- 2011: **rgeos** package (Bivand and Rundel, 2017)
- 2016-17: **sf** - simple features for R (Pebesma, 2018a)
- 2017-18: **stars** - spatiotemporal tidy arrays for R (Pebesma, 2018b)

Further reading: https://geocompr.robinlovelace.net/intro.html#the-history-of-r-spatial

Source: Robin Lovelace, Jakub Nowosad, Jannes Muenchow

R-spatial

- **sf** and **sp** are the most important R packages to handle vector data
  - **sf** is a successor of **sp** but its still evolving
  - Moreover, many other R packages depend on the functions and classes for the **sp** package
- **raster** is an extension of spatial data classes to work with rasters
- It is also easy to connect R with a GIS software such as GRASS GIS (**rgrass7**), SAGA GIS (**RSAGA**), QGIS (**RQGIS** and **qgisremote**), and ArcGIS (**arcgisbinding**)

Further reading: https://geocompr.robinlovelace.net/intro.html#the-history-of-r-spatial

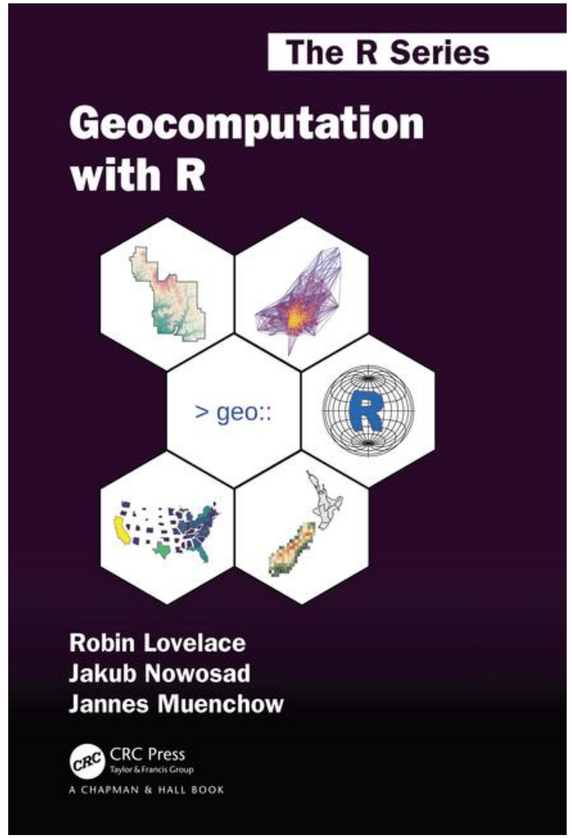
Resources

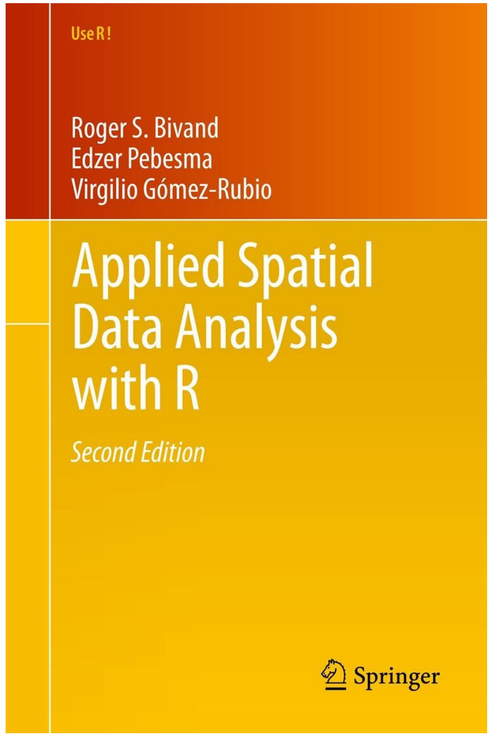
Online

- Geocomputation with R
- Applied Spatial Statistics with R
- Spatial Data Science with R
- Using Spatial Data with R
- Spatial Data Science
- r-spatial

Paper

- Applied Spatial Data Analysis with R
- An Introduction to R for Spatial Analysis and Mapping

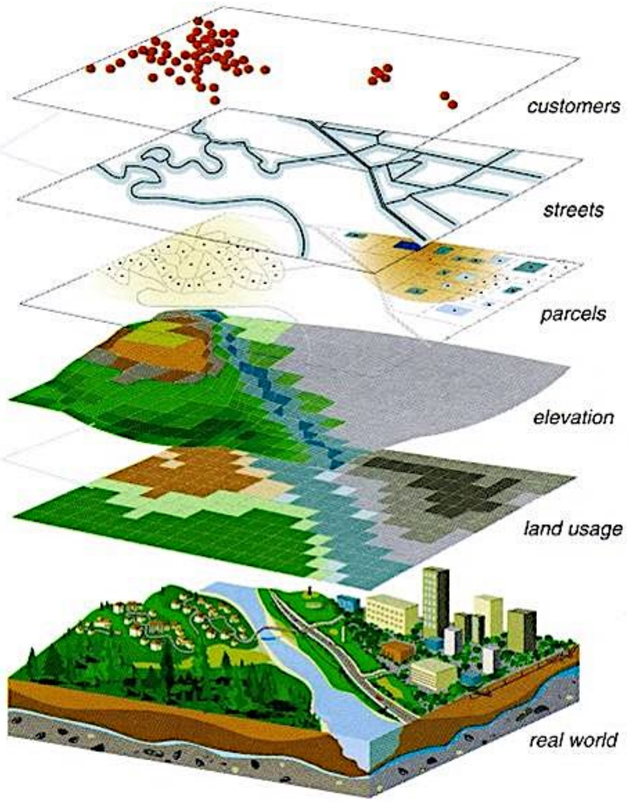




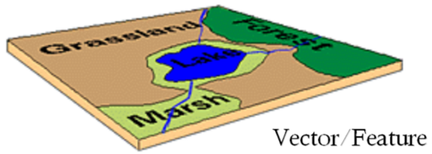
Getting started

Representing physical features

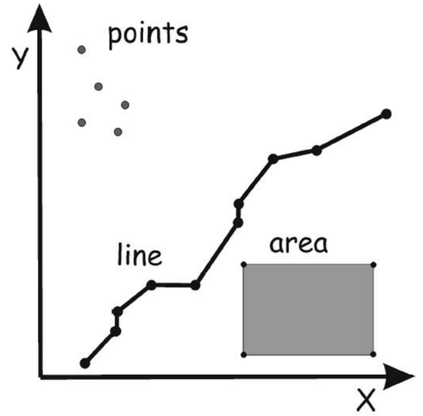
Two data models for representing digitally geographic data:
the vector[1] and **the raster**[2] data model.

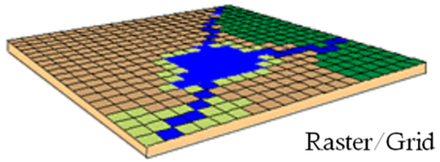


Images from Andy Lyons
The Berkeley R Language Beginner Study Group

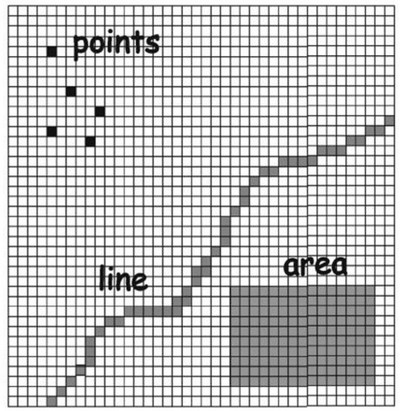


Vector/Feature data





Raster/Grid data



[1] Hijmans, Robert J. (2019). *Raster: Geographic Data Analysis and Modeling*. R package version 2.8-19. URL: https://CRAN.R-project.org/package=raster.

[2] Pebesma, Edzer (2018). "Simple Features for R: Standardized Support for Spatial Vector Data". In: *The R Journal* 10.1, pp. 439-446. URL: https://journal.r-project.org/archive/2018/RJ-2018-009/index.html.

Getting started

Creating spatial objects

Three options:

- from scratch (e.g. digitizing[1], geocoding[2])
- “promote” a data frame including a geometry column (e.g. Census)
- import a GIS file (e.g. shapefiles, rasters, geopackages)

[1] **Digitizing** is the process by which coordinates from a map, image, or other sources of data are converted into a digital format in a GIS.

[2] **Geocoding** is the process of taking a text-based description of a location, such as an address or the name of a place, and returning geographic coordinates, frequently latitude/longitude pair, to identify a location on the Earth's surface.

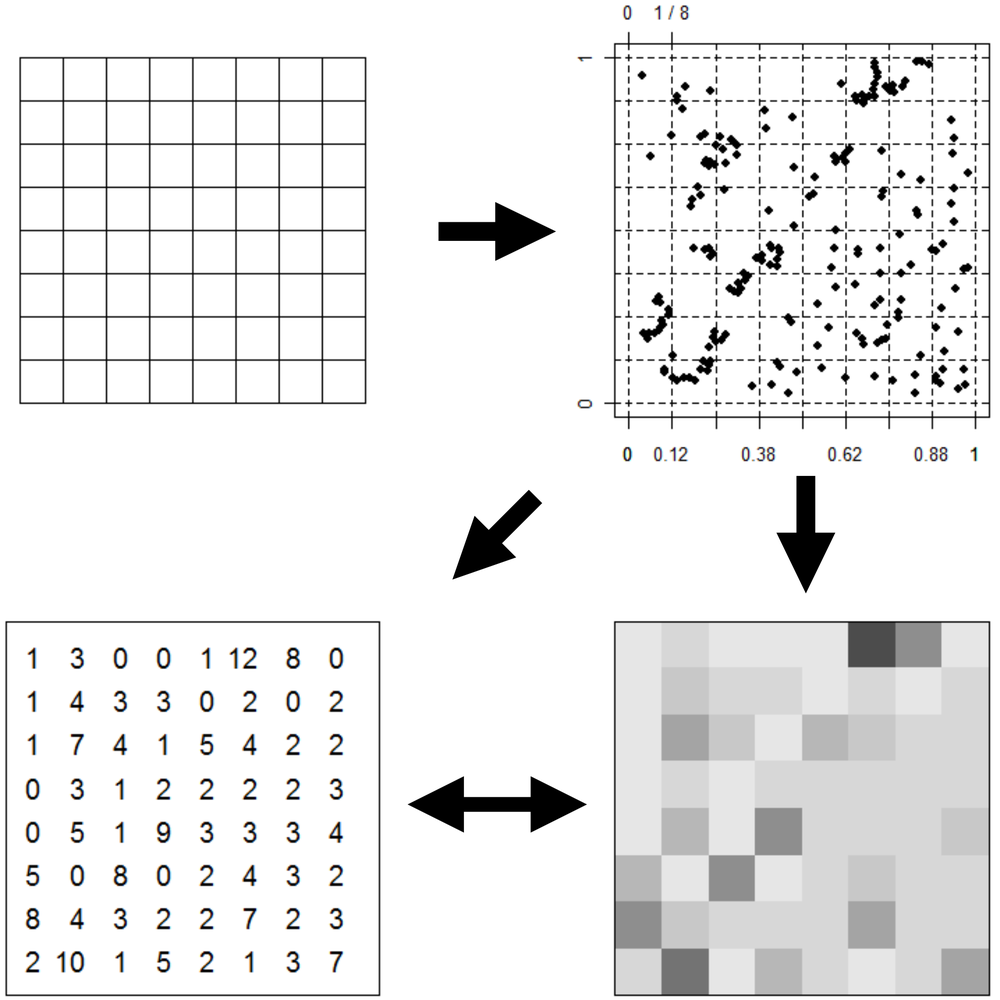
Find more at http://wiki.gis.com/wiki/index.php/Digitizing

Spatial raster data

Spatial raster data

Raster package

- **read**, **write** and **manipulate** gridded spatial data
- basic and high-level analysis **functions**
- **processing** of large files



Using a raster to summarize a point pattern

Image adapted from https://en.wikipedia.org/wiki/Raster_graphics#/media/File:The_use_of_a_raster_data_structure_to_summarize_a_point_pattern.gif

Spatial raster data

Lots of real world applications

- Raster or "gridded" data are stored as a grid of values which are rendered on a map as pixels.
- **Each pixel value represents an area on the Earth's surface.**

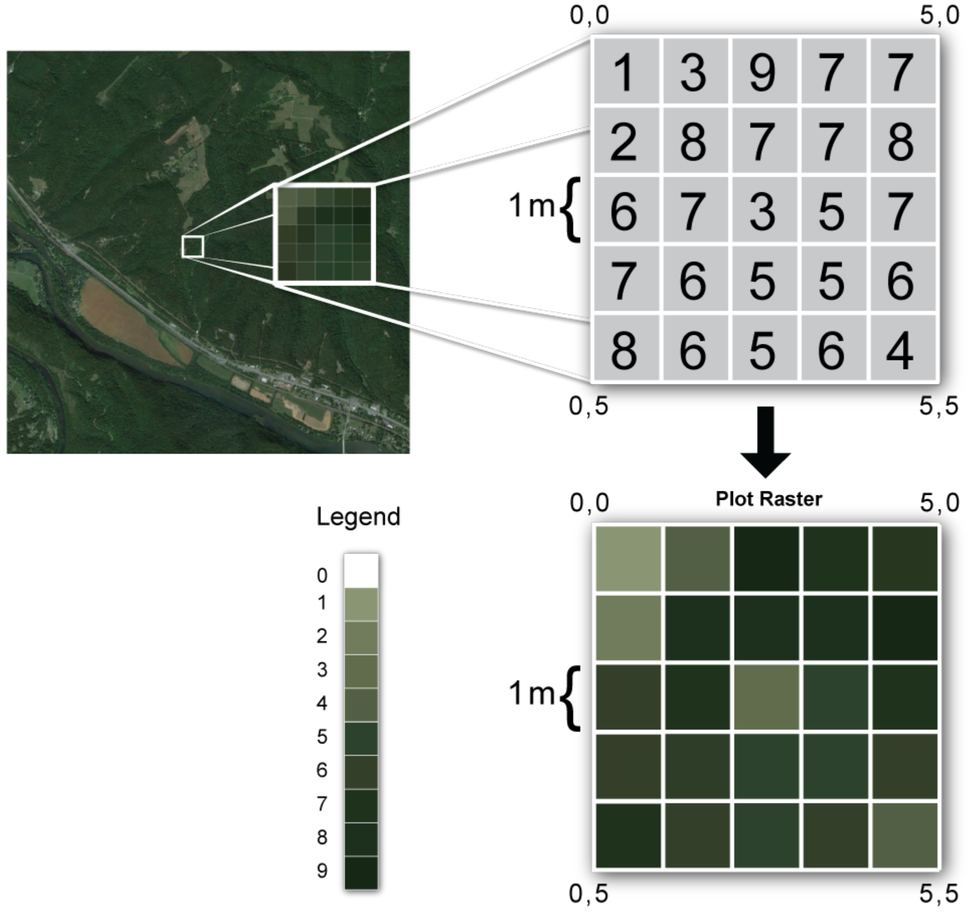


Image: National Ecological Observatory Network
https://www.neonscience.org/resources/learning-hub/tutorials/dc-raster-data-r

Spatial raster data

Resolution

- Each pixel value represents an area on the Earth's surface
- Resolution represents the area on the ground that each pixel covers
- The best way to view resolution units is to look at the coordinate reference system string

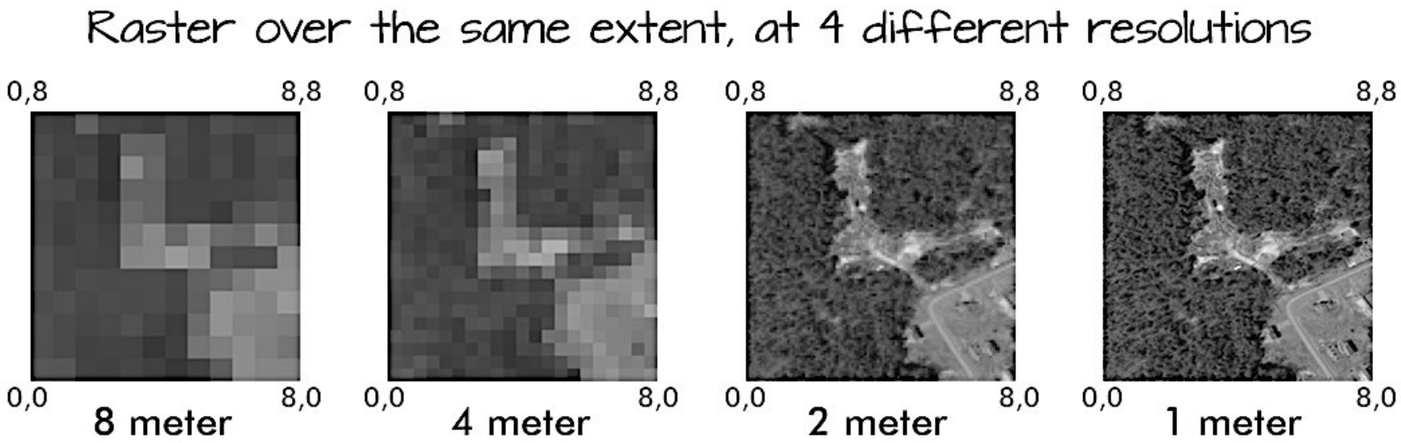
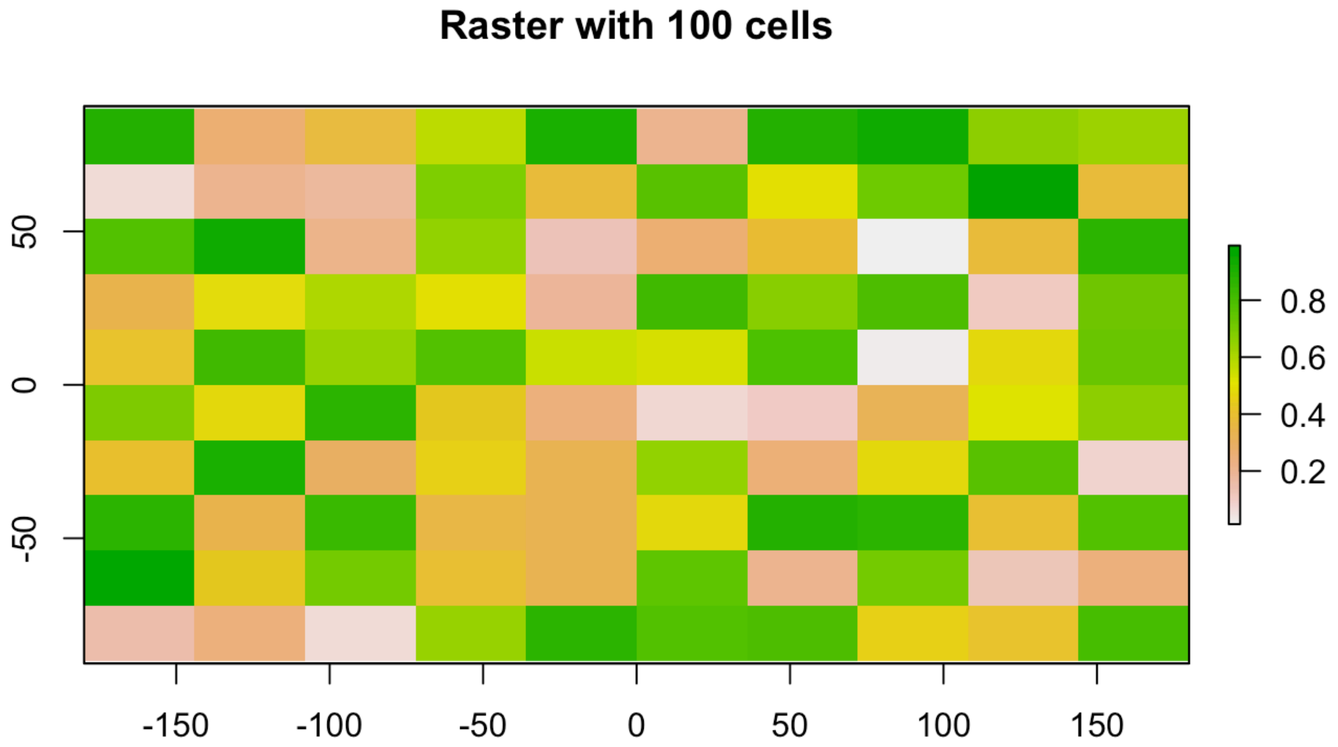


Image: National Ecological Observatory Network
https://www.neonscience.org/resources/learning-hub/tutorials/dc-raster-data-r

Spatial raster data

Creating Raster objects from scratch. Give it a try and see!

```
library(raster)

r <- raster(ncol=10, nrow=10)

ncell(r)

hasValues(r)

values(r) <- 1:ncell(r)

set.seed(0)

values(r) <- runif(ncell(r))

hasValues(r)

inMemory(r)

values(r)[1:10]

plot(r, main='Raster with 100 cells')
```



Spatial raster data

Raster algebra

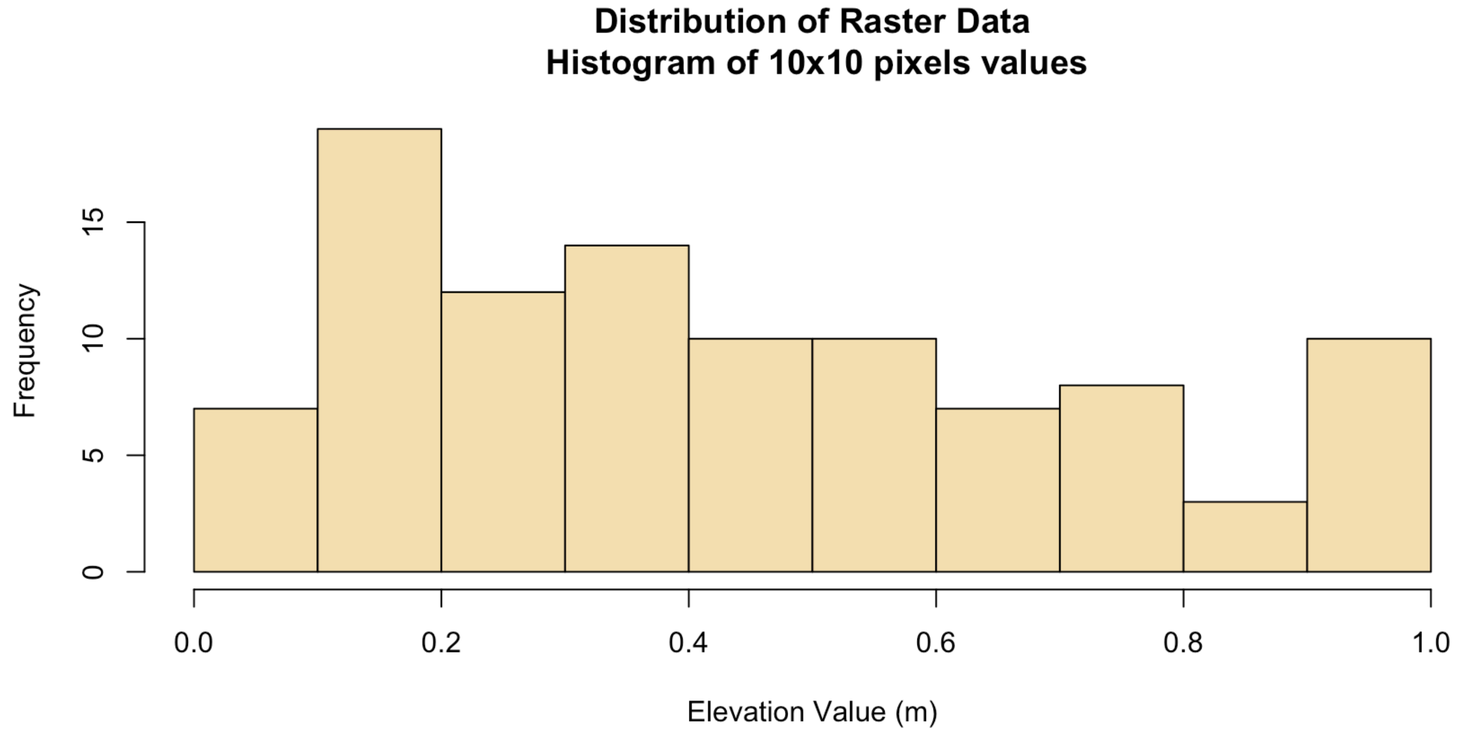
```
r
values(r)[1:10]

s <- r + 10
values(s)[1:10]

s <- sqrt(s)
values(s)[1:10]

s <- s * r + 5
values(s)[1:10]

r[] <- runif(ncell(r)) # replacements
values(r)[1:10]

r <- round(r)
values(r)[1:10]

r <- r == 1
values(r)[1:10]
```

- Many generic functions that allow for simple and elegant raster algebra have been implemented for Raster objects

Spatial raster data

Raster histogram

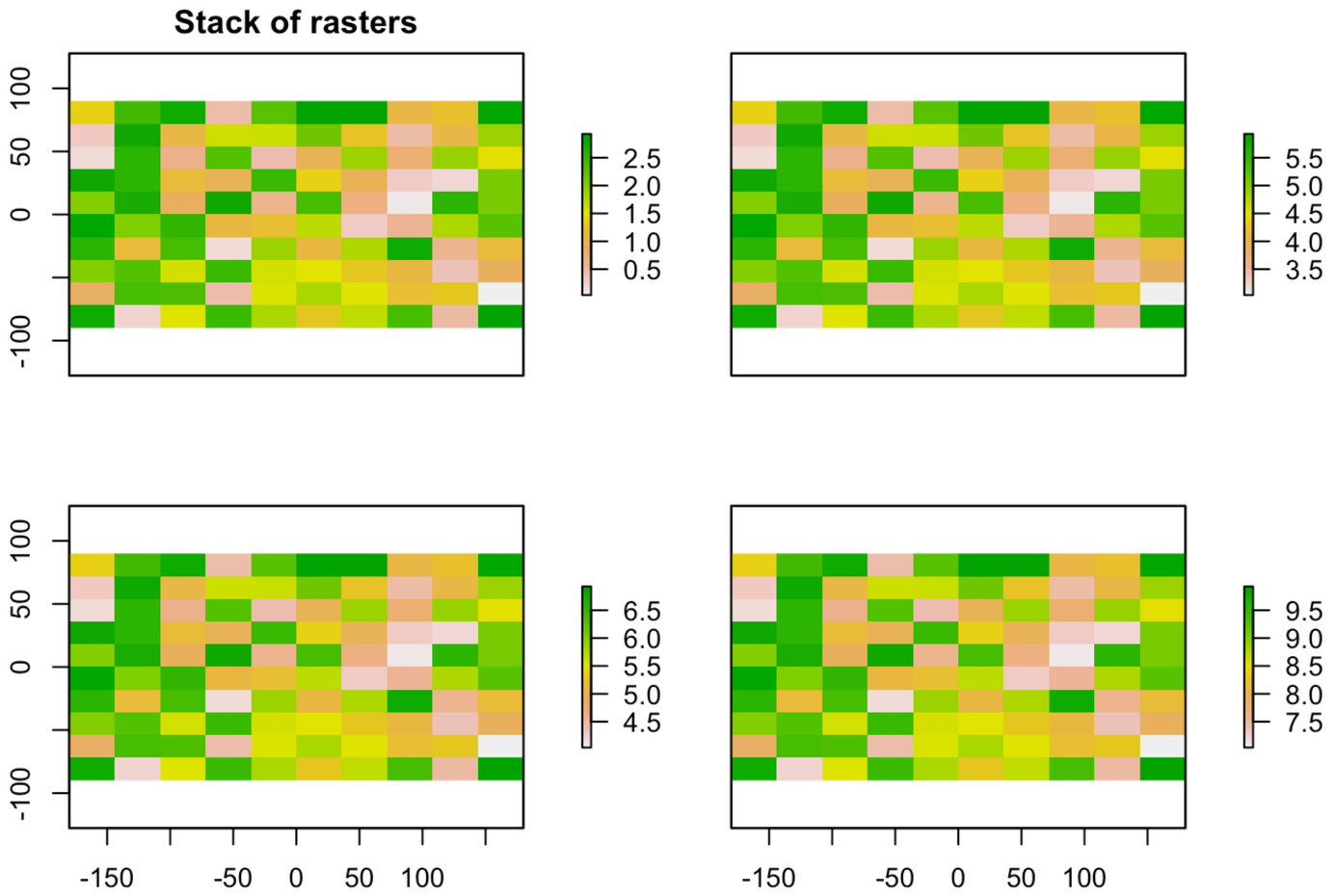
```
hist(s,
     main="Distribution of Raster Data\n Histogram of 10x10 pixels values",
     xlab="Elevation Value (m)",
     ylab="Frequency",
     col="wheat")
```



Spatial raster data

Multiple layers

```
r <- raster(ncol=10, nrow=10)

r[] <- runif(ncell(r))

s <- stack(r, r+1)

q <- stack(r, r+2, r+4, r+6)

x <- r + s + q

x

plot(x, main='Stack of rasters')
```



Spatial raster data

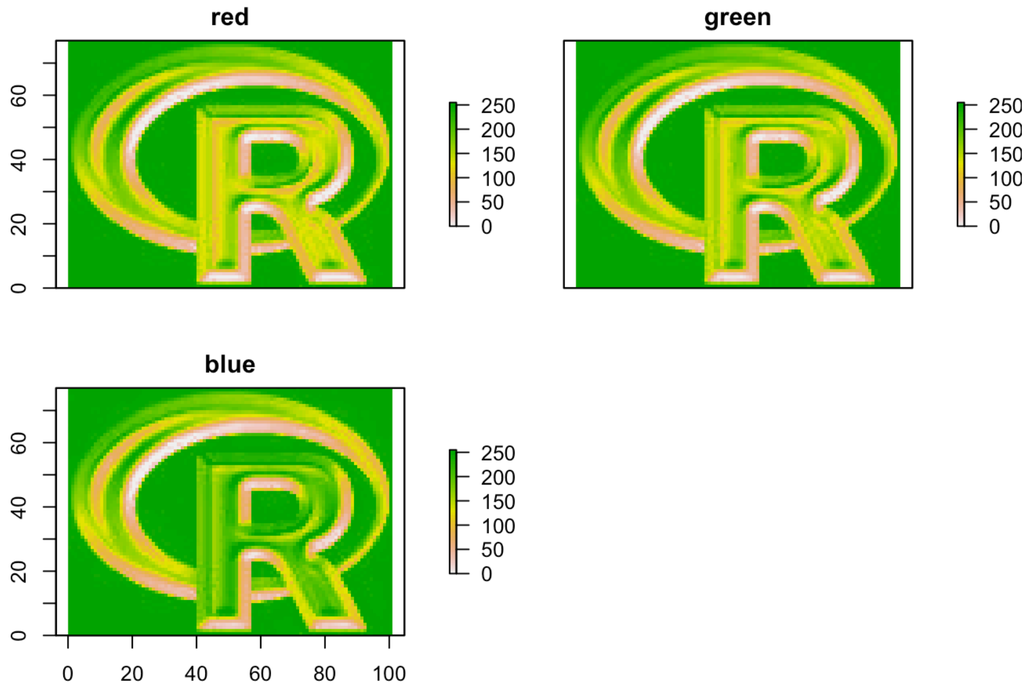
Raster data types

- **RasterLayer** - a single layer raster
- **RasterStack** - multi-layer raster
- **RasterBrick** - multi-layer raster (from a single file on disk, faster)

Spatial raster data

Multiple layers

```
b <- brick(system.file("external/rlogo.grd", package="raster"))

plot(b)

plotRGB(b, r=1, g=2, b=3)
```



Spatial raster data

Summary functions

(min, max, mean, prod, sum, median, cv, range)

```
a <- mean(r,s)
values(a)[1:10]

b <- sum(r,s)

st <- stack(r, s, a, b)

sst <- sum(st)
sst

cellStats(st, "sum")

cellStats(sst, "sum")
```

- Summary functions always return a RasterLayer object
- Perhaps this is not obvious when using functions like min, sum or mean

Spatial raster data ... to be continued

Many others geometric operations on raster data ...

Check: https://geocompr.robinlovelace.net/geometric-operations.html#raster-vector

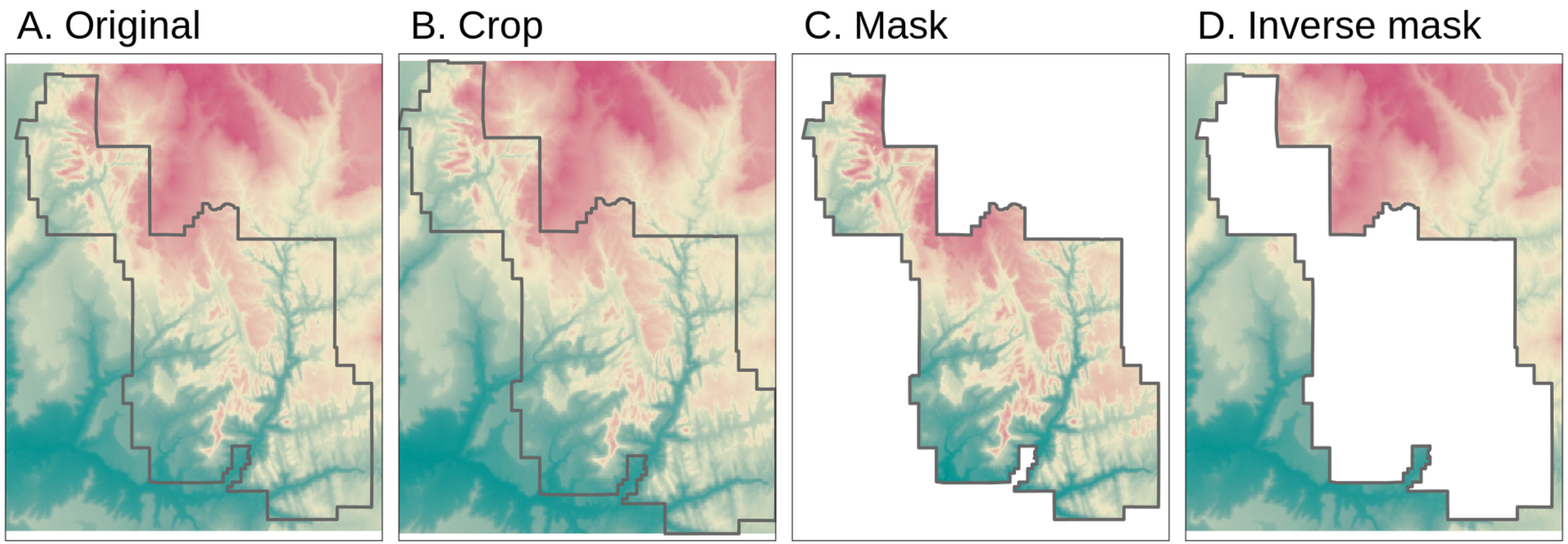


Illustration of raster cropping and raster masking

Image: Robin Lovelace, Jakub Nowosad, Jannes Muenchow

Spatial vector data

Spatial vector data

The sf package

```
devtools::install_github("r-spatial/sf") # development version
# or
install.packages("sf") # stable version
```

The **sf** package in an R implementation of Simple Features

This package incorporates:

- A relatively new spatial data class system in R
- Functions for reading and writing data
- Tools for spatial operations on vectors

Most of the functions in this package start with a prefix **st_**

You need a recent version of the **GDAL**, **GEOS**, **Proj.4**, and **UDUNITS** libraries installed for this to work on Mac and Linux. More information on that at https://github.com/r-spatial/sf

Spatial vector data

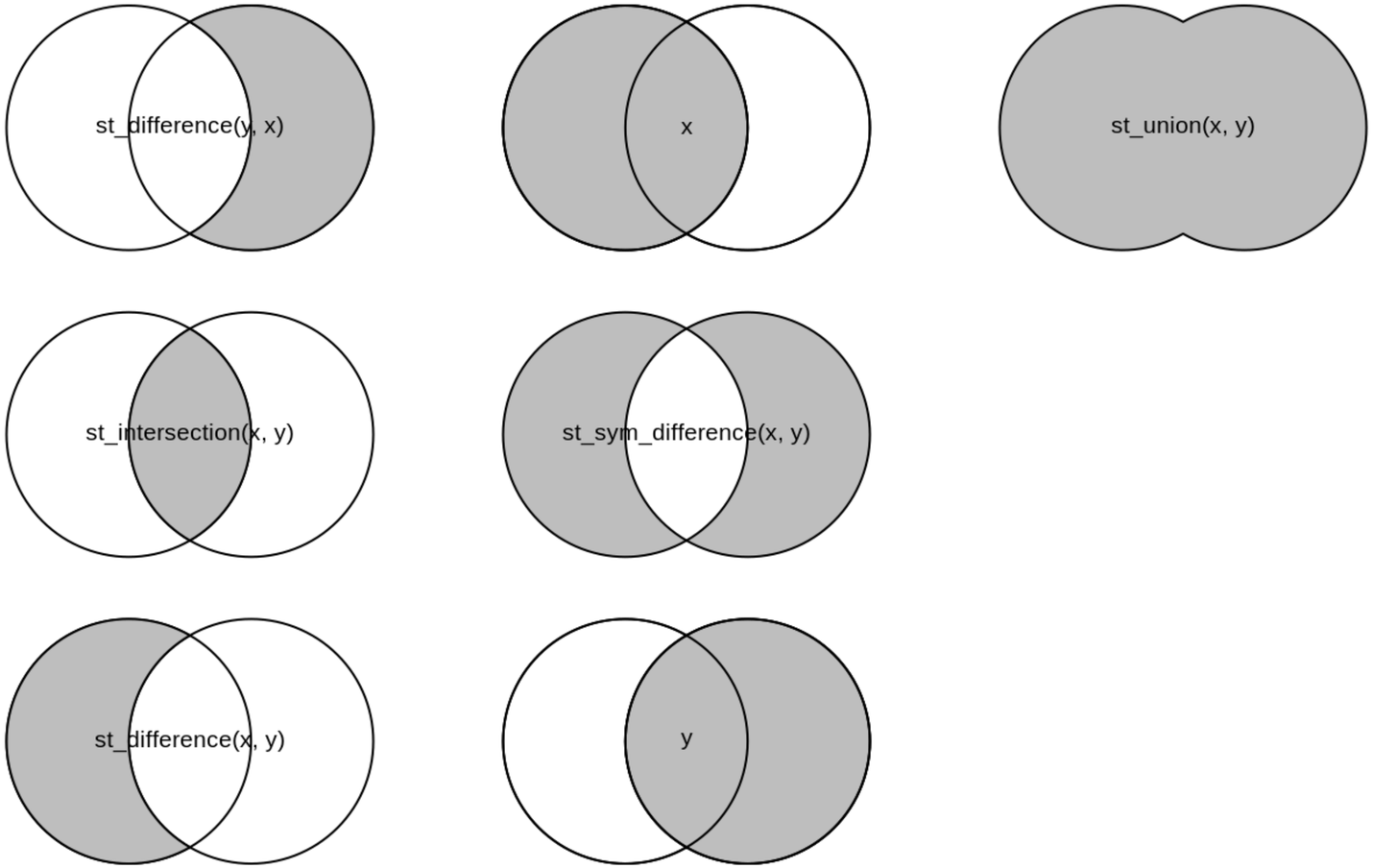
Simple feature geometry types

- Simple feature geometries are a way to describe the geometries of features
- By features it mean things that have a geometry, and eventually other attributes
- The big seven (most commonly used simple features geometries):

type	description
`POINT`	single point geometry
`MULTIPOINT`	set of points
`LINESTRING`	single linestring (two or more points connected by straight lines)
`MULTILINESTRING`	set of linestrings
`POLYGON`	exterior ring with zero or more inner rings, denoting holes
`MULTIPOLYGON`	set of polygons
`GEOMETRYCOLLECTION`	set of the geometries above

Spatial vector data

Spatial equivalents of logical operators

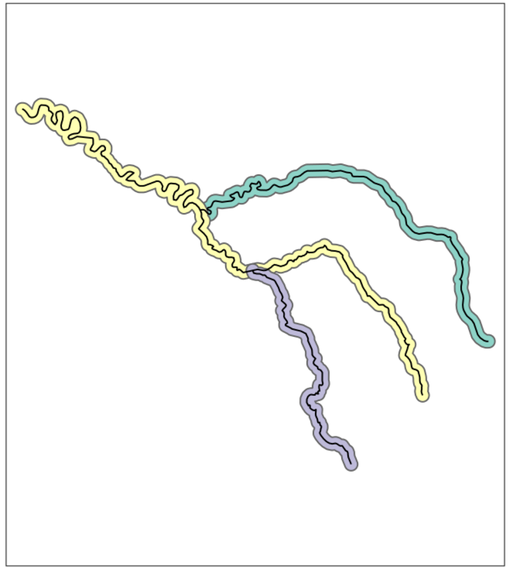


Images: https://geocompr.robinlovelace.net/geometric-operations.html

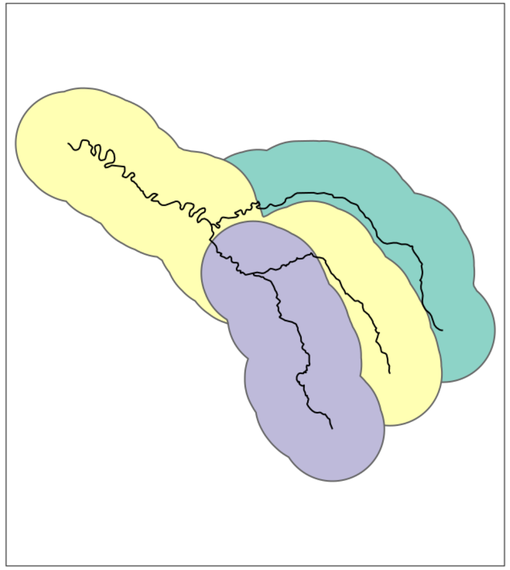
Spatial vector data

Many other spatial operations

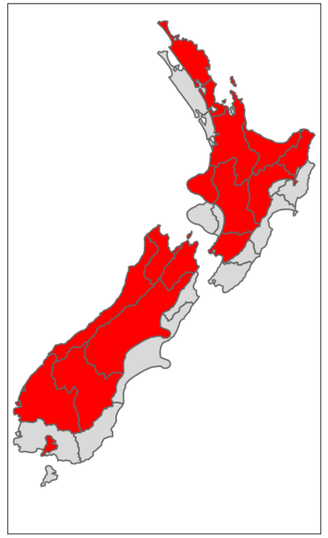
5 km buffer



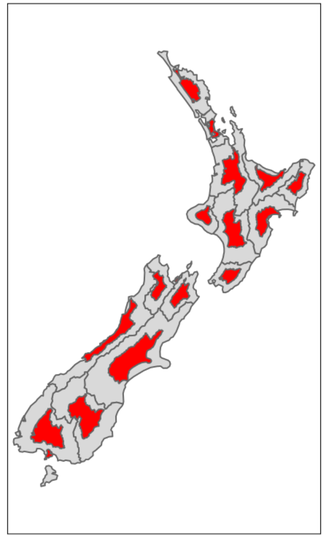
50 km buffer



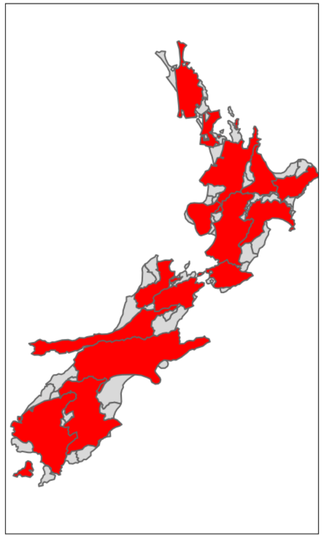
Shift



Scale

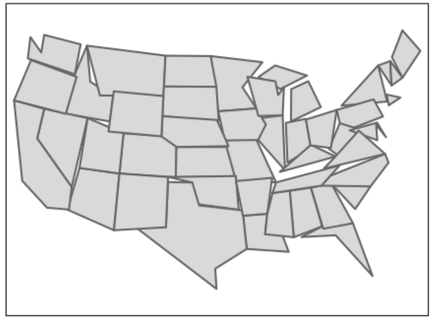


Rotate

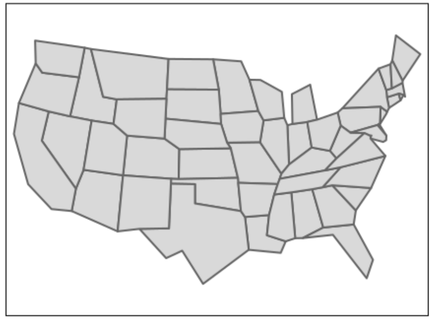


Original data

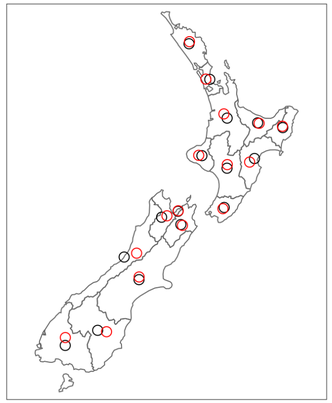
st_simplify

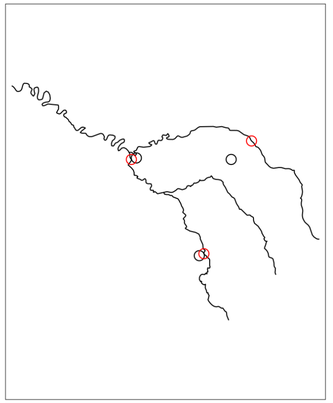


ms_simplify



Centroids (black points) and 'points on surface' (red points)





Images: https://geocompr.robinlovelace.net/geometric-operations.html

Spatial vector data

Basics

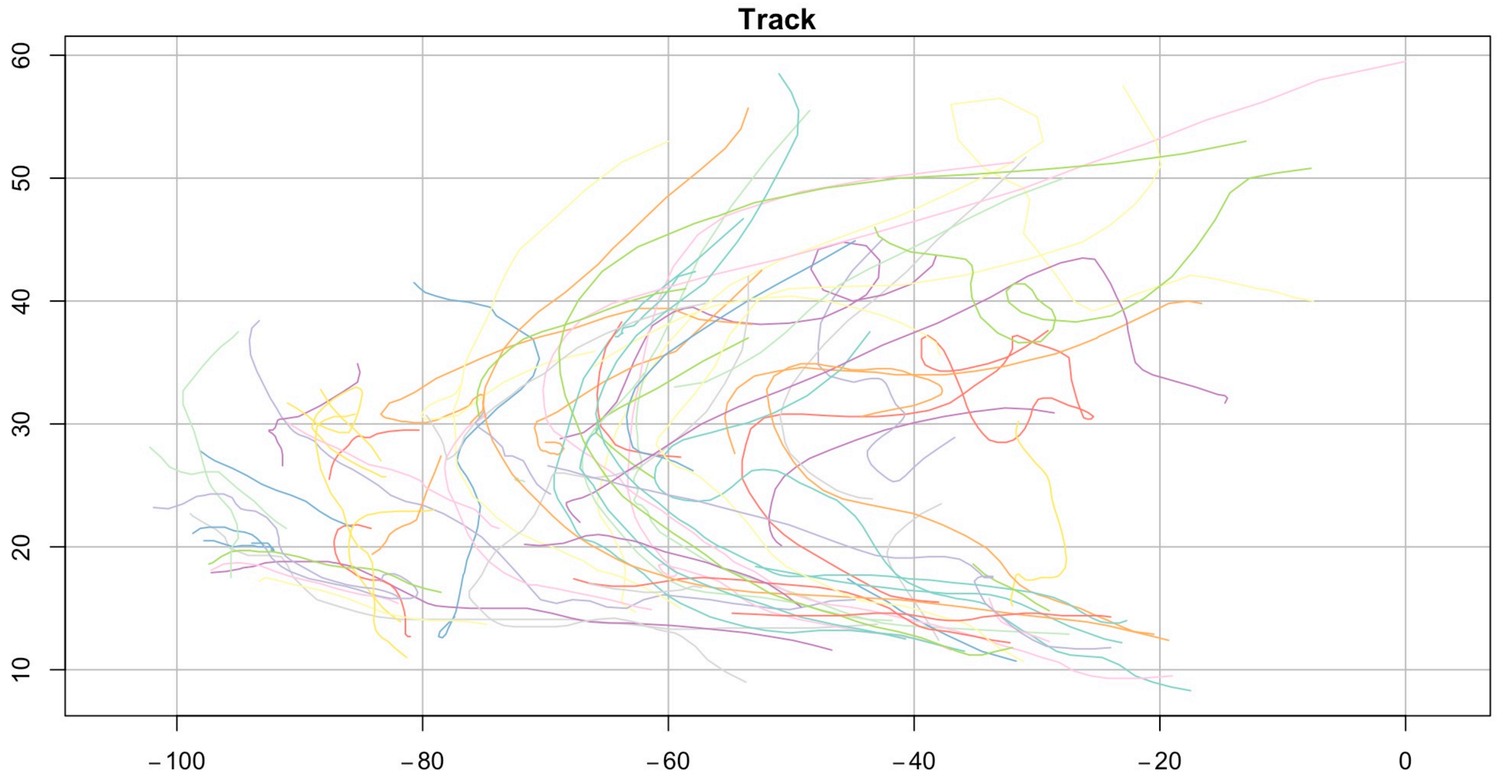
```
library(tidyverse)

library(sf)
```

- Pipes (%>%)
  `a %>% b() %>% c() %>% d()`
  Get **a** do **b** then **c** then **d**
- **Packaged data** vs. Imported data
- Select and filter

Spatial vector data

Line example

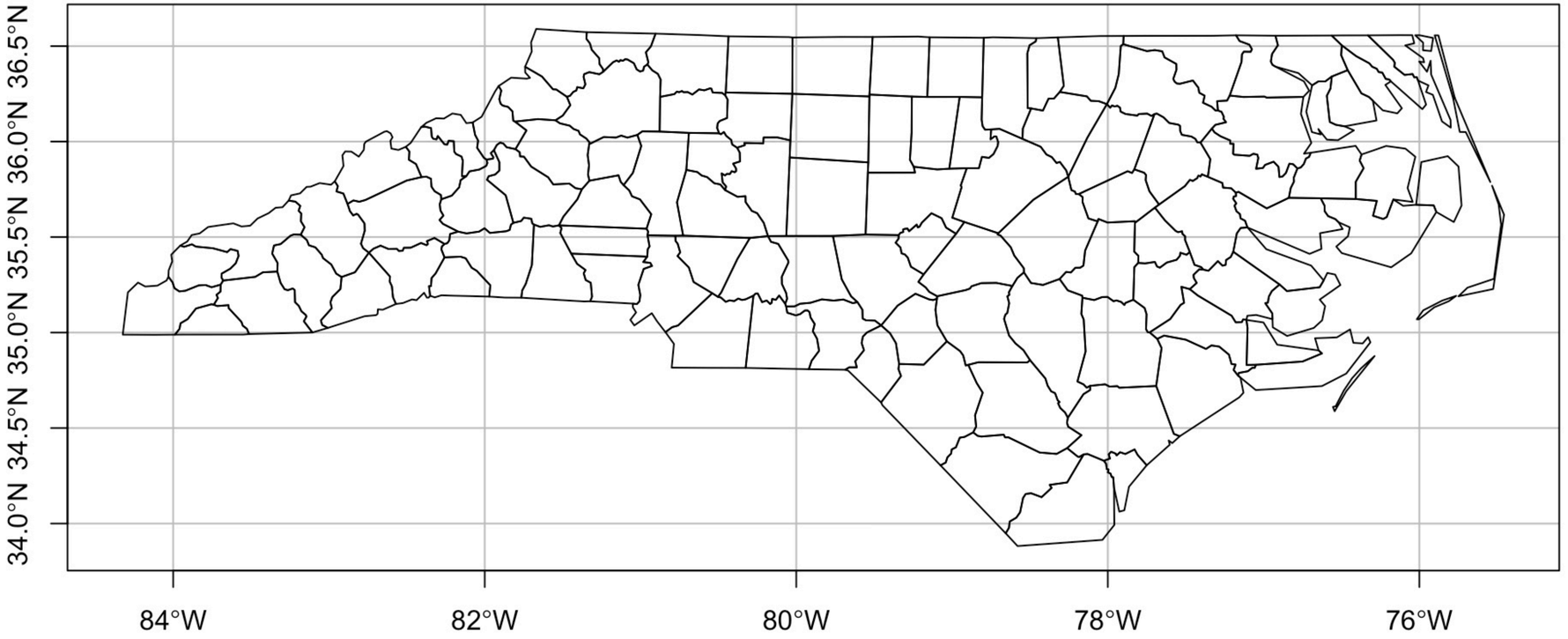
```
storms_xyz_feature <- system.file("shape/storms_xyz_feature.shp", package="sf") %>%
   st_read() %>%
   st_as_sf()

plot(storms_xyz_feature, graticule = TRUE, axes = TRUE)
```



Spatial vector data

Polygon example

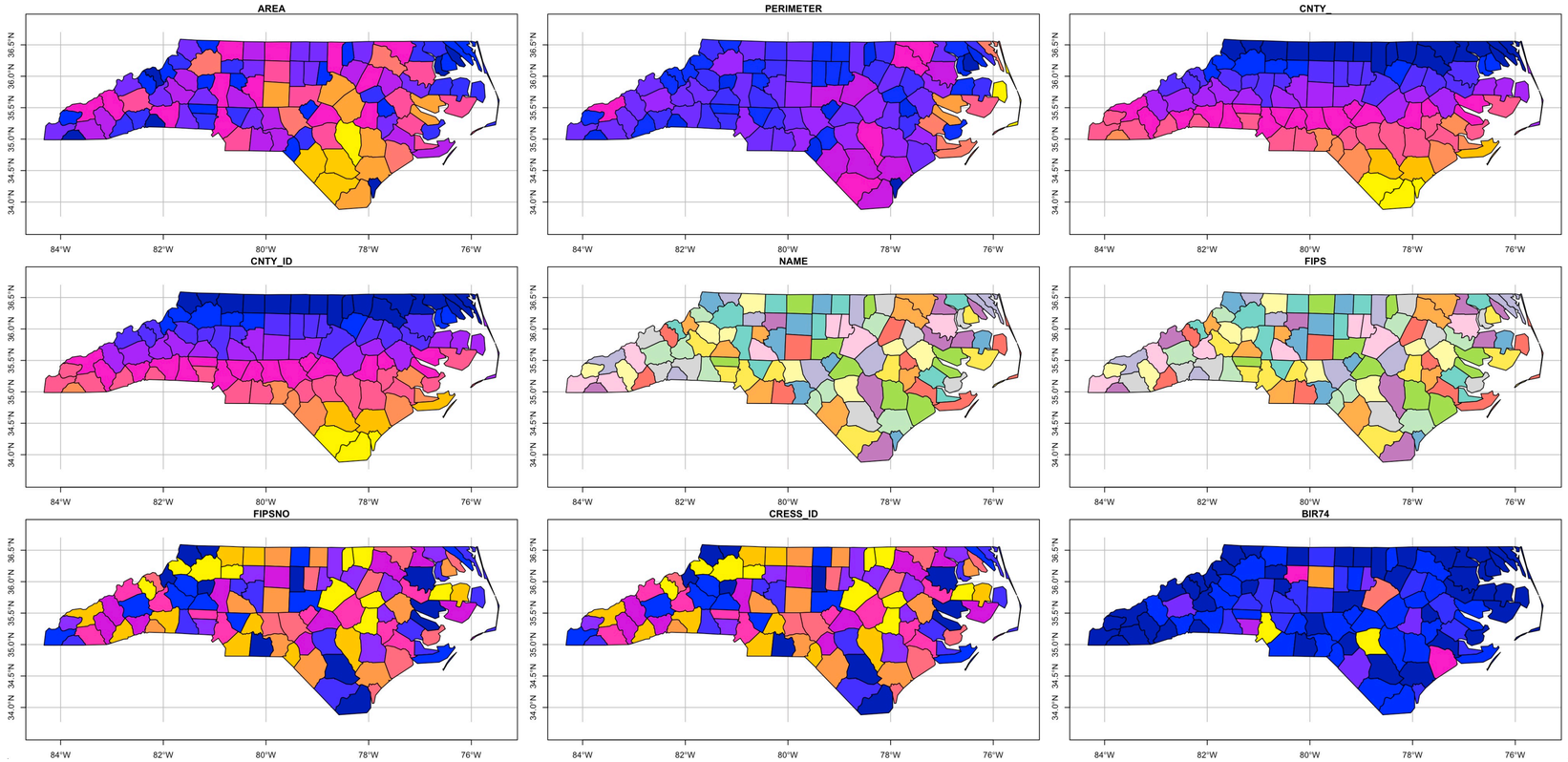
```
nc <- system.file("shape/nc.shp", package="sf") %>%
   st_read() %>%
   st_as_sf()

plot(nc$geometry, graticule = TRUE, axes = TRUE)
```



Spatial vector data

Attributes

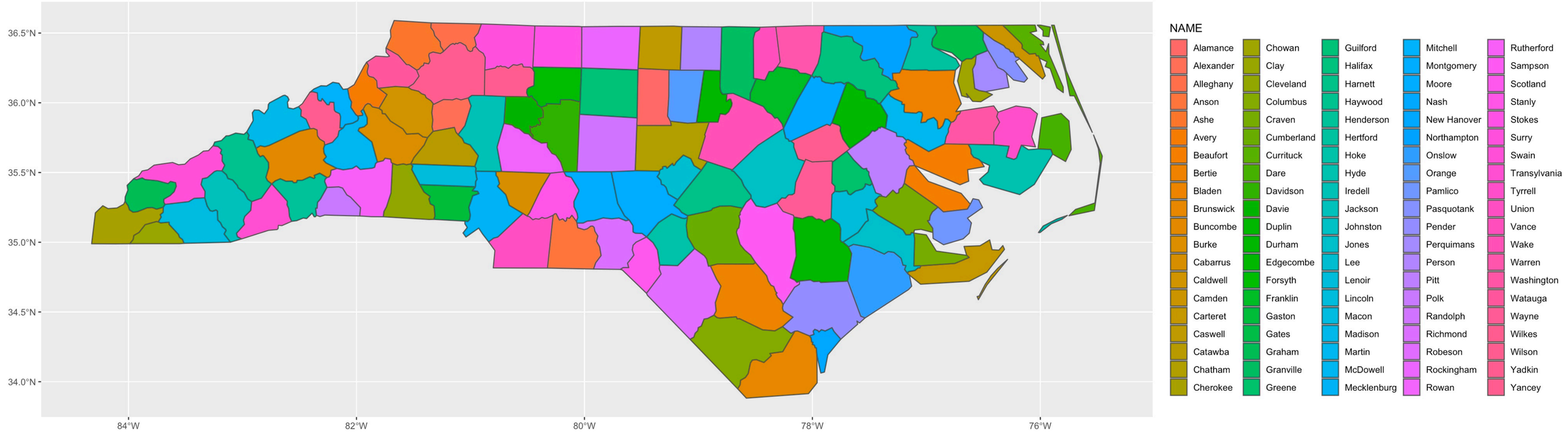
```
nc <- system.file("shape/nc.shp", package="sf") %>%
   st_read() %>%
   st_as_sf()

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



Spatial vector data

ggplot (more next)

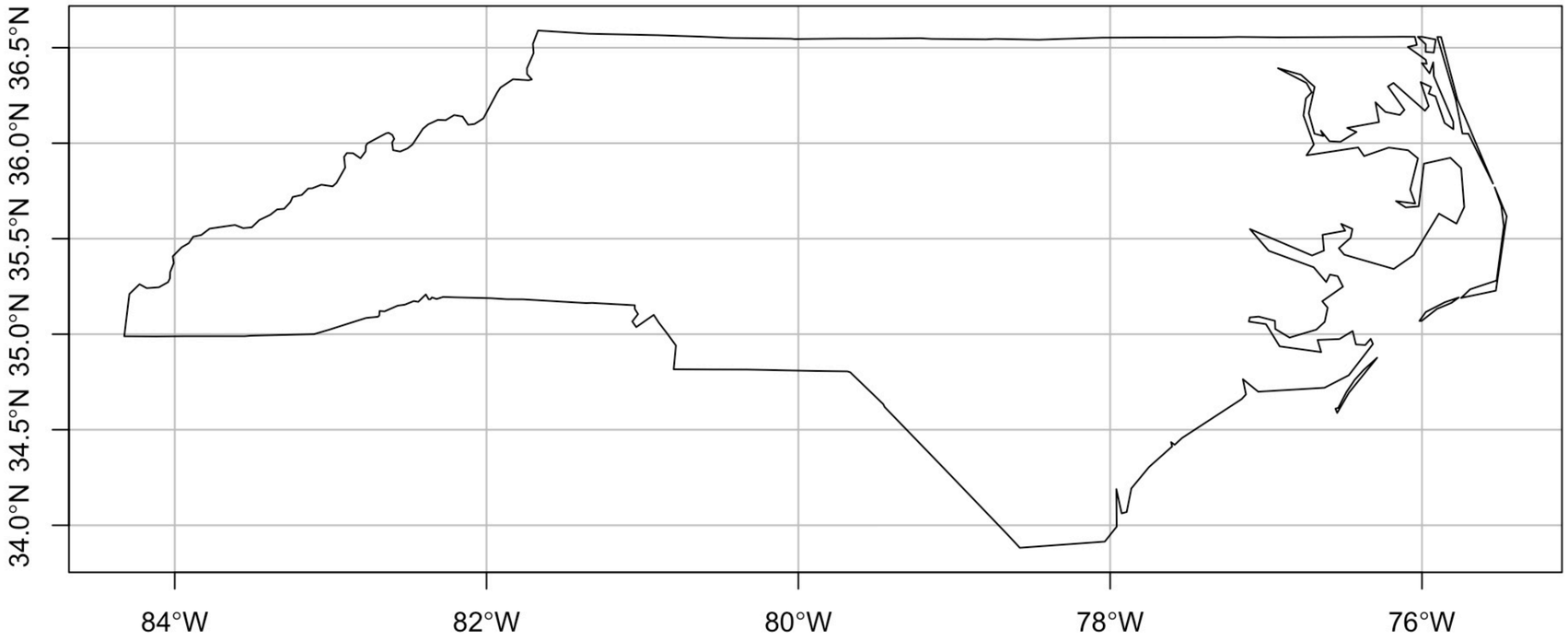
```
ggplot(nc) +
   geom_sf(aes(fill = NAME))
```



Spatial vector data

Dissolve features

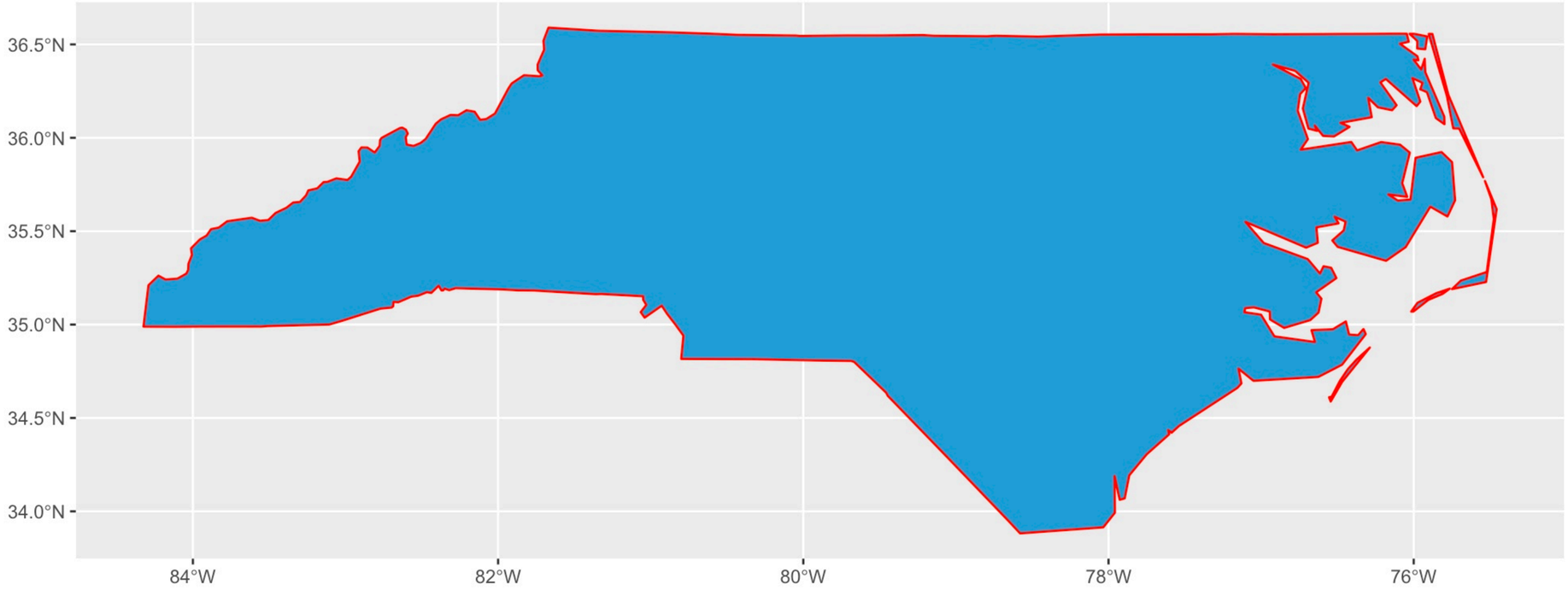
```
nc %>%
   group_by() %>%
   summarise() %>%
   plot(graticule = TRUE, axes = TRUE)
```



Spatial vector data

Dissolve features

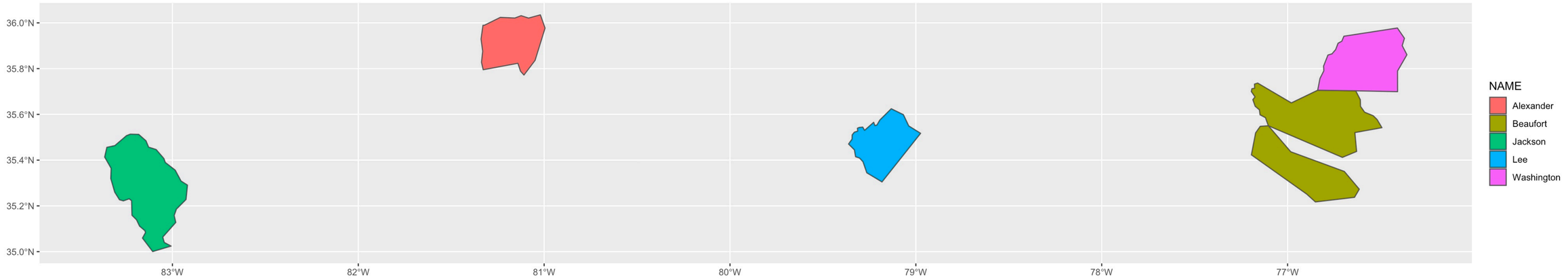
```
nc %>%
   group_by() %>%
   summarise() %>%
   ggplot() +
   geom_sf(fill = "#4B9CD3",
           color = "red")
```



Spatial vector data

Filter attributes

```
nc %>%
   filter(NAME %in% c("Alexander", "Beaufort", "Lee", "Jackson", "Washington")) %>%
   ggplot() +
   geom_sf(aes(fill = NAME))
```

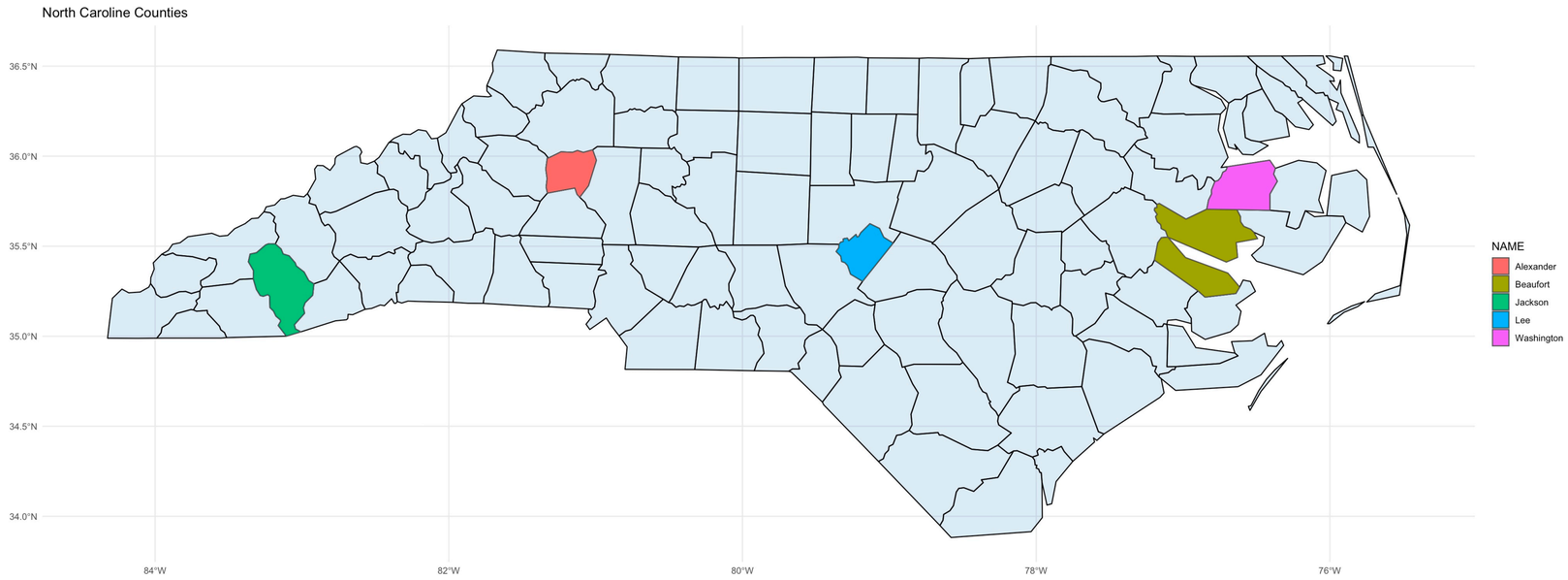


Mapping

Mapping

ggplot

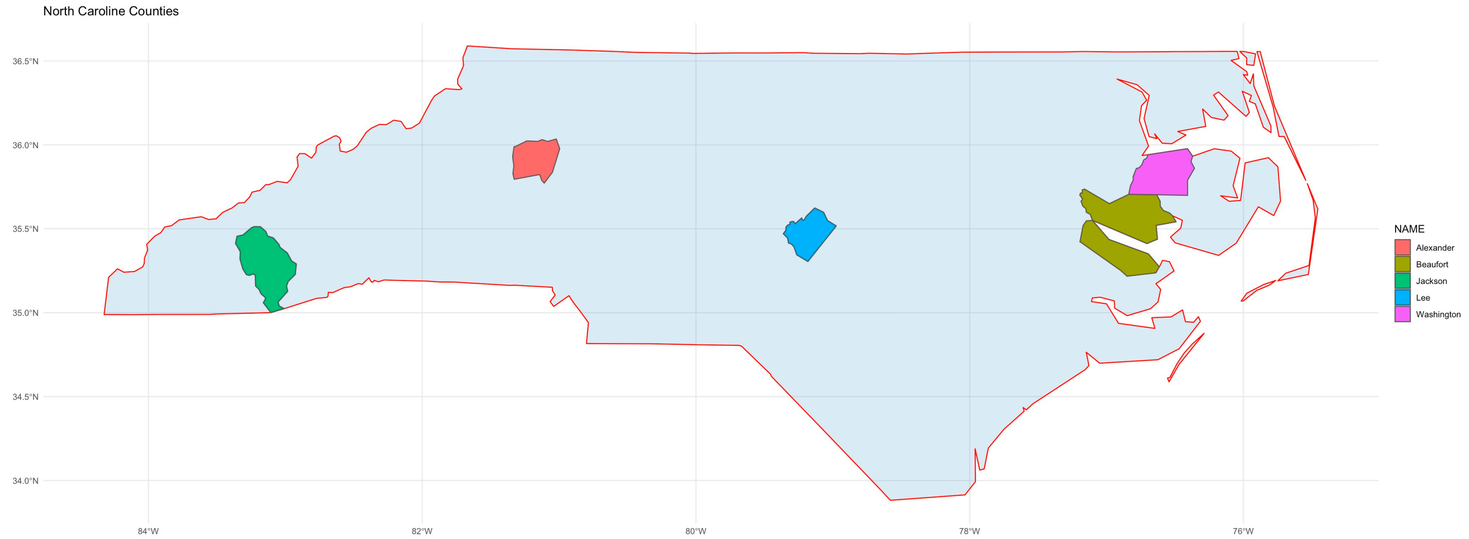
```
ggplot() +
   geom_sf(data = nc,
           fill = "#4B9CD3", alpha = 0.2,
           color = "black") +
   geom_sf(data = nc %>%
              filter(NAME %in% c("Alexander", "Beaufort", "Lee", "Jackson", "Washington")),
           aes(fill = NAME)) +
   labs(title = "North Caroline Counties",
        legend = "Selected Counties") +
   theme_minimal()
```



Mapping

ggplot

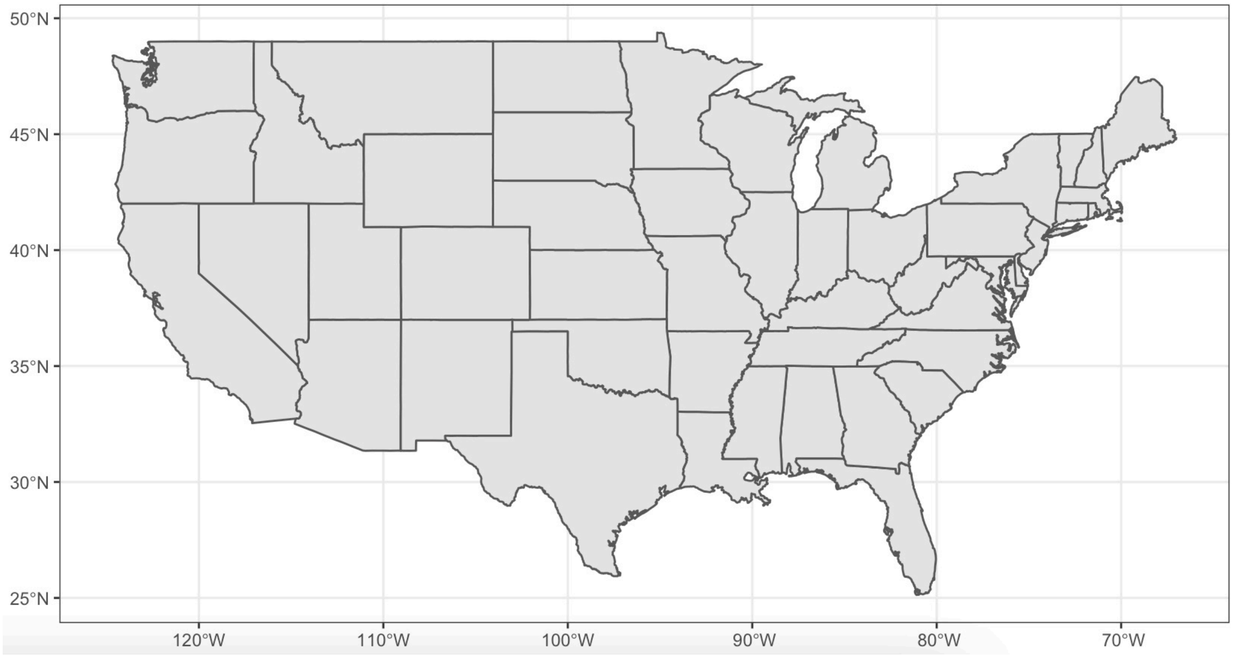
```
ggplot() +
   geom_sf(data = nc %>%
              group_by() %>%
              summarise(),
           fill = "#4B9CD3", alpha = 0.2,
           color = "red") +
   geom_sf(data = nc %>%
              filter(NAME %in% c("Alexander", "Beaufort", "Lee", "Jackson", "Washington")),
           aes(fill = NAME)) +
   labs(title = "North Caroline Counties",
        legend = "Selected Counties") +
   theme_minimal()
```



Mapping

ggplot

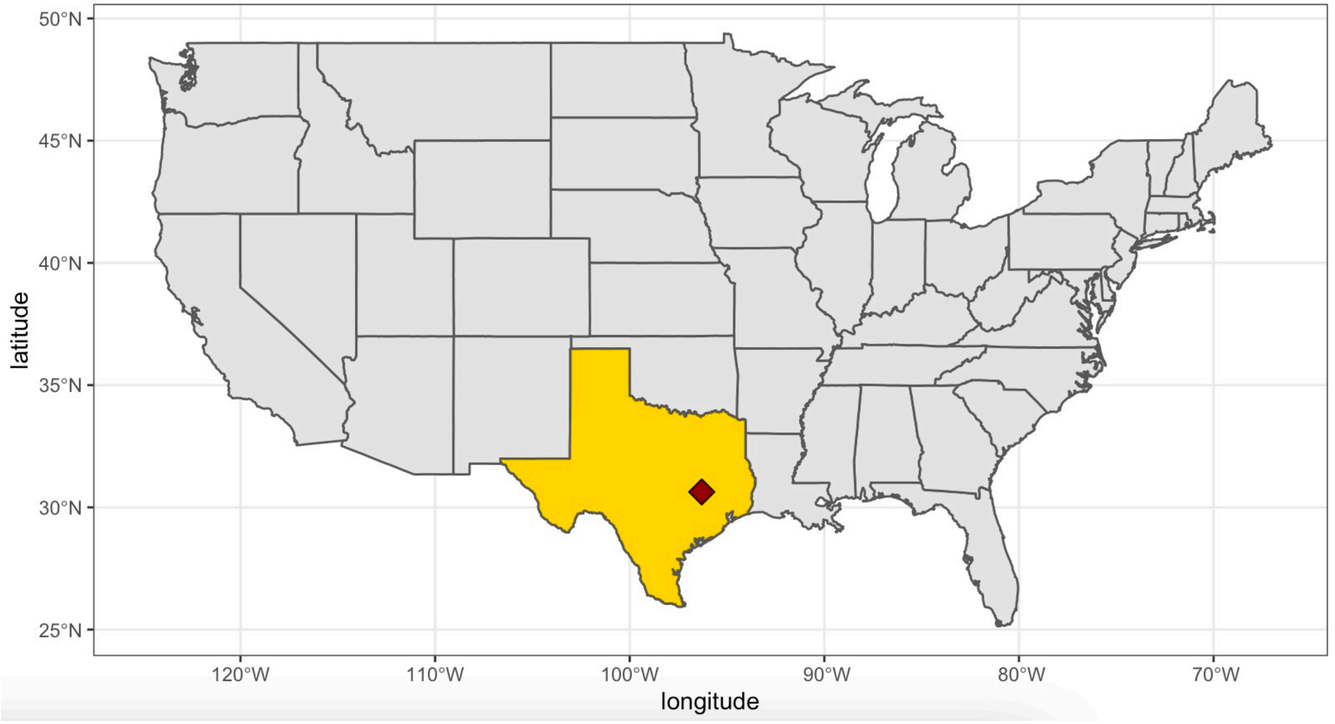
```
library(maps)

some_point <- data.frame(longitude = c(-96.30),
                         latitude  = c(30.63))

us <- st_as_sf(map("state", plot = FALSE, fill = TRUE))
us

class(us)

ggplot(data = us) +
   geom_sf()
```

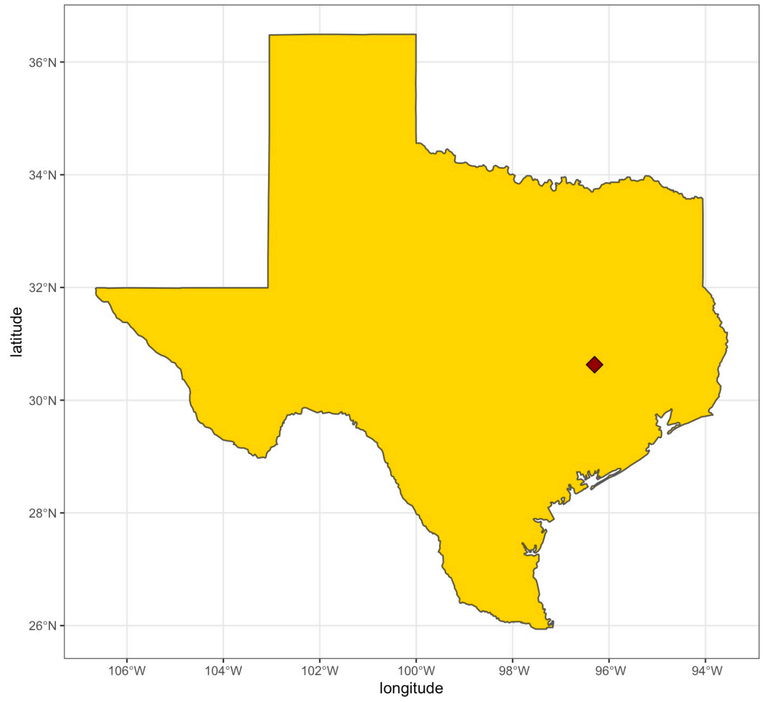


Mapping

ggplot

```
ggplot() +
   geom_sf(data = us) +
   # geom_sf(data = us %>% filter(ID == "texas"), fill = "gold") +
   geom_point(data = some_point,
              aes(x = longitude, y = latitude),
              size = 4, shape = 23, fill = "darkred")
```

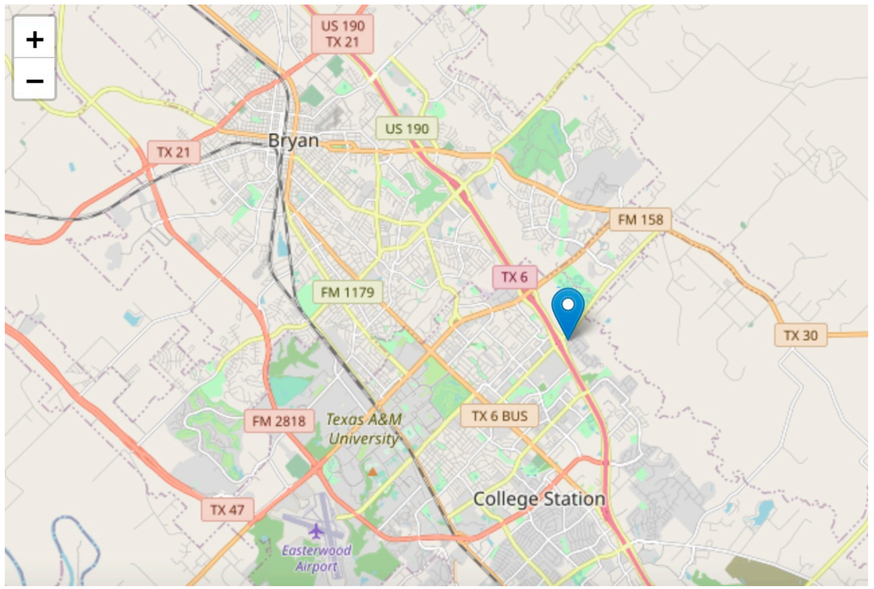


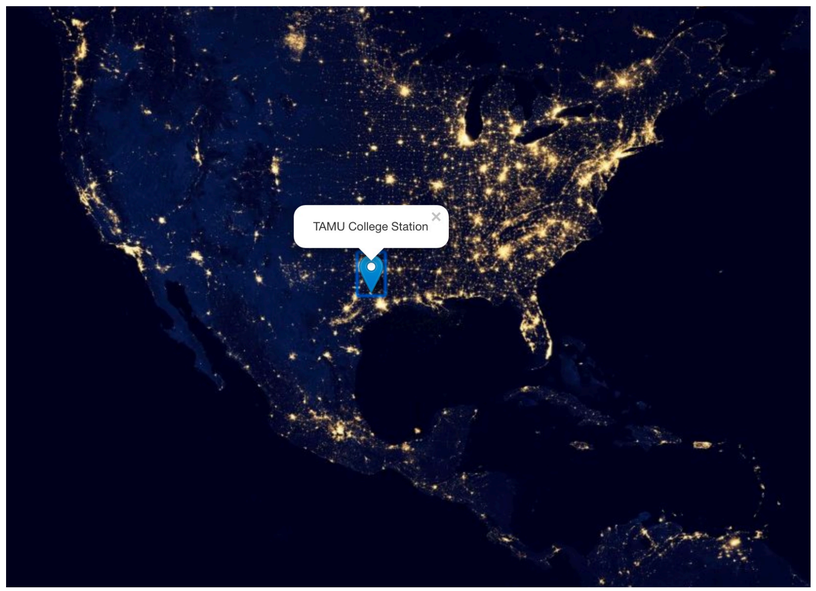


Mapping

leaflet

```
library(leaflet)

TxGIS = c("TAMU College Station”)

leaflet() %>%
addProviderTiles("NASAGIBS.ViirsEarthAtNight2012") %>%
   addMarkers(lng = c(-96.3),
              lat = c(30.6),
              popup = TxGIS)
```



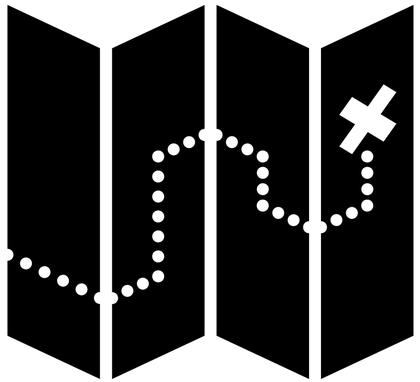


- Check other base-maps / tiles provider
  http://leaflet-extras.github.io/leaflet-providers/preview/

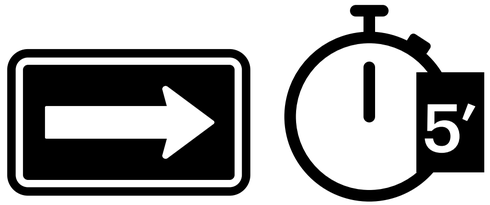
Walking, cycling, and driving time-distances

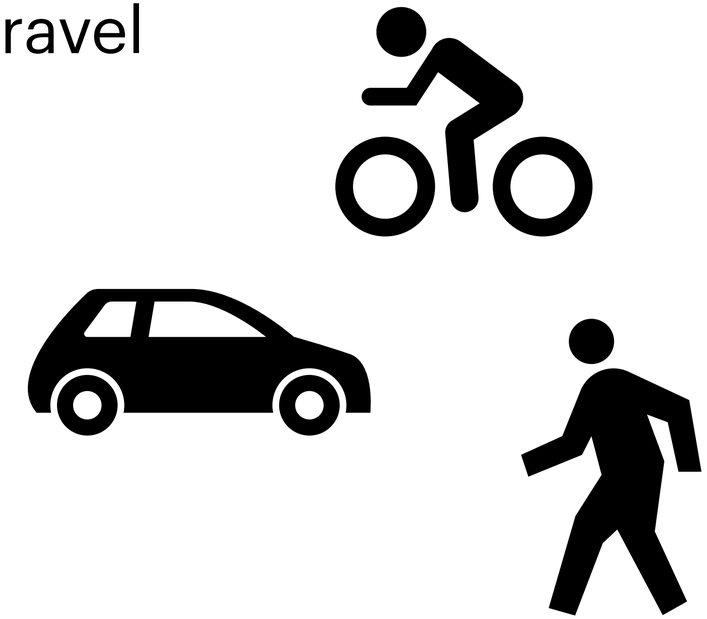
Walking, cycling, and driving time-distances

Goal



- Define a location
- Find 5-minute distances
  using different means of travel





Walking, cycling, and driving time-distances

Step 1: install libraries and get an API

```
remotes::install_github(“walkerke/mapboxapi")

library(mapboxapi)

mb_access_token("pk.ey...", install = TRUE)
```

- To get started, sign up for a Mapbox account and generate an access token.
- Set your public or secret token for use in the package with mb_access_token()
- Once you’ve set your token, you are ready to get started using the package.

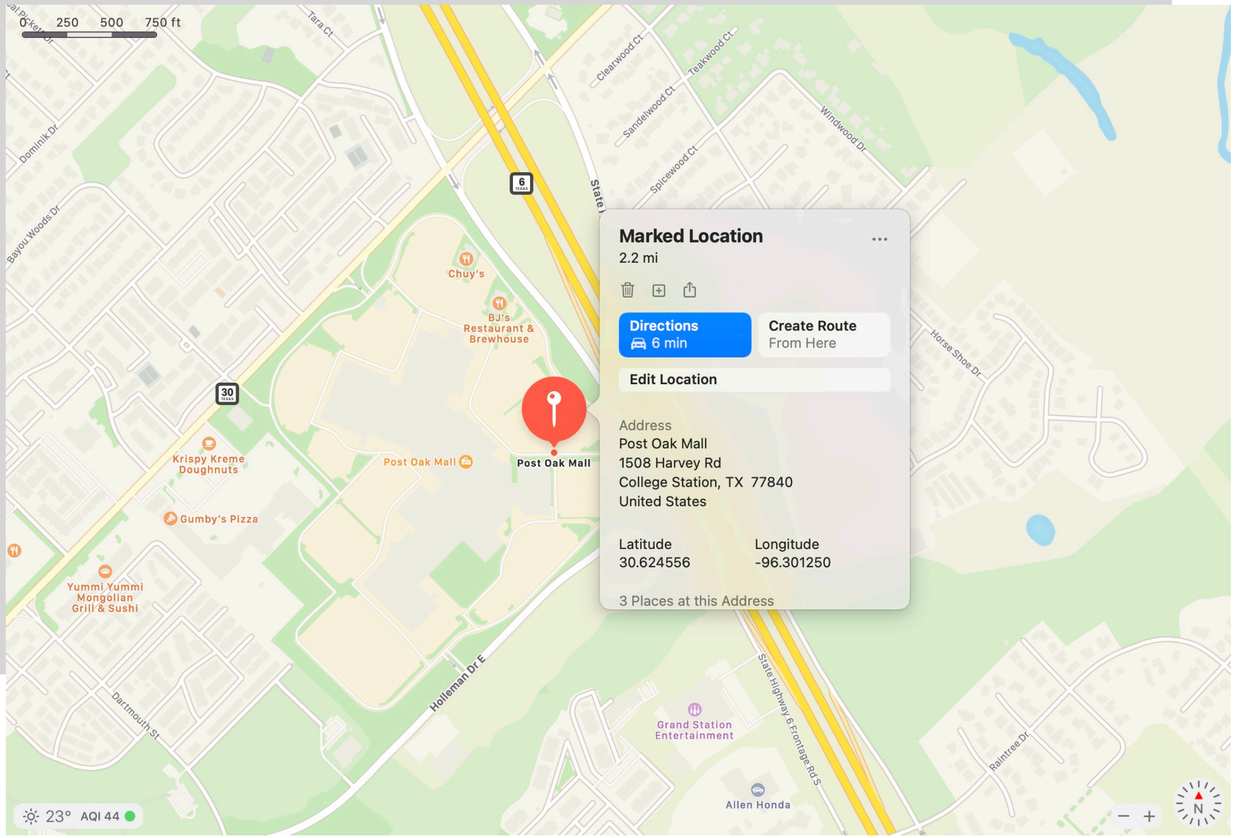
https://docs.mapbox.com/api/

https://account.mapbox.com

Walking, cycling, and driving time-distances

Step 2: geocode an address

```
address <- "Texas A&M University, Langford Architecture Bldg 3137, College Station, TX 77843”

address <- c(-96.301250, 30.624556)

walk_5min <- mb_isochrone(address,
                          profile = "walking",
                          time = 5)

bike_5min <- mb_isochrone(address,
                          profile = "cycling",
                          time = 5)

drive_5min <- mb_isochrone(address,
                           profile = "driving",
                           time = 5)
```



Walking, cycling, and driving time-distances

Step 3: pick a basemap

```
library(ggmap)
library(gridExtra)

bbox = c(left = as.numeric(st_bbox(drive_5min)$xmin-0.05),
         bottom = as.numeric(st_bbox(drive_5min)$ymin-0.025),
         right = as.numeric(st_bbox(drive_5min)$xmax+0.05),
         top = as.numeric(st_bbox(drive_5min)$ymax+0.025))

map <- get_stamenmap(bbox,
                     maptype = "toner-2011",
                     zoom = 13)

theme_set(theme_bw())
```

Walking, cycling, and driving time-distances

Step 3: pick a basemap

```
ggmap(map) +
   theme_void() +
   theme(plot.title = element_text(colour = "orange"),
         panel.border = element_rect(colour = "black",
                                     fill = NA, size = .7))
```

Walking, cycling, and driving time-distances

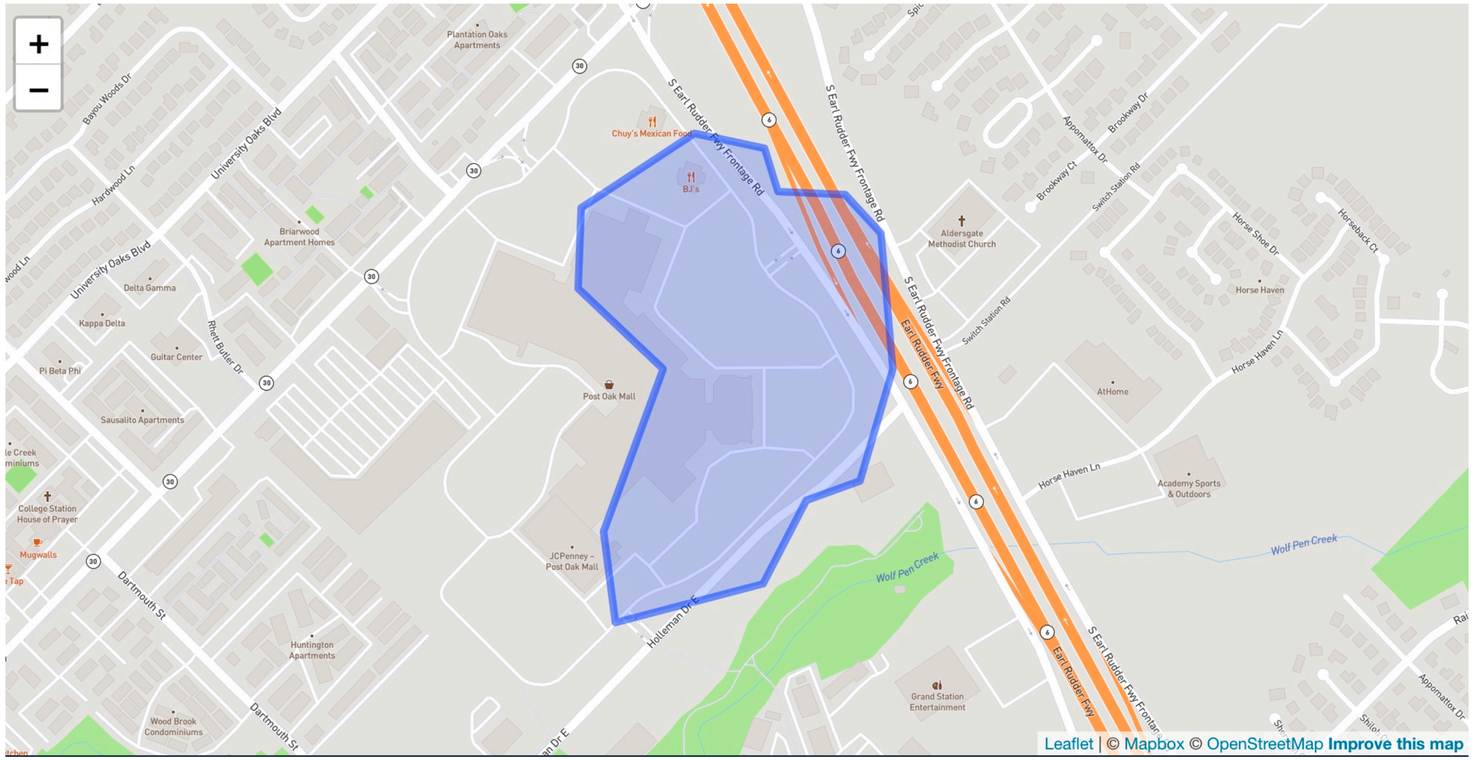
Step 4: the distance map

```
ggmap(map) +
   geom_sf(data = drive_5min,
           aes(fill = "driving"),
           color = "white", alpha=0.6, linetype = "blank",
           show.legend = TRUE, inherit.aes = FALSE) +
   geom_sf(data=bike_5min,
           aes(fill="cycling"),
           color="white", alpha=0.8, linetype = "blank",
           show.legend = TRUE, inherit.aes = FALSE) +
   geom_sf(data=walk_5min,
           aes(fill="walking"),
           color="white", alpha=0.7, linetype = "blank",
           show.legend = TRUE, inherit.aes = FALSE) +
   scale_fill_manual(values = c("walking" = "green",
                                "cycling" = "blue2",
                                "driving" = "red"),
                     breaks =  c("walking", "cycling", "driving")) +
   labs(x="",
        y="",
        title="5-minute time-distances",
        fill="") +
   theme(legend.justification="left",
         panel.background=element_rect(fill="grey", colour="grey", size=0.5, linetype="solid"),
         panel.grid.major=element_line(size=0.2, linetype="solid", colour="white"),
         panel.grid.minor=element_line(size=0.2, linetype="solid", colour="white")) # -> temp2
```

Walking, cycling, and driving time-distances

Step 5: an interactive Leaflet map

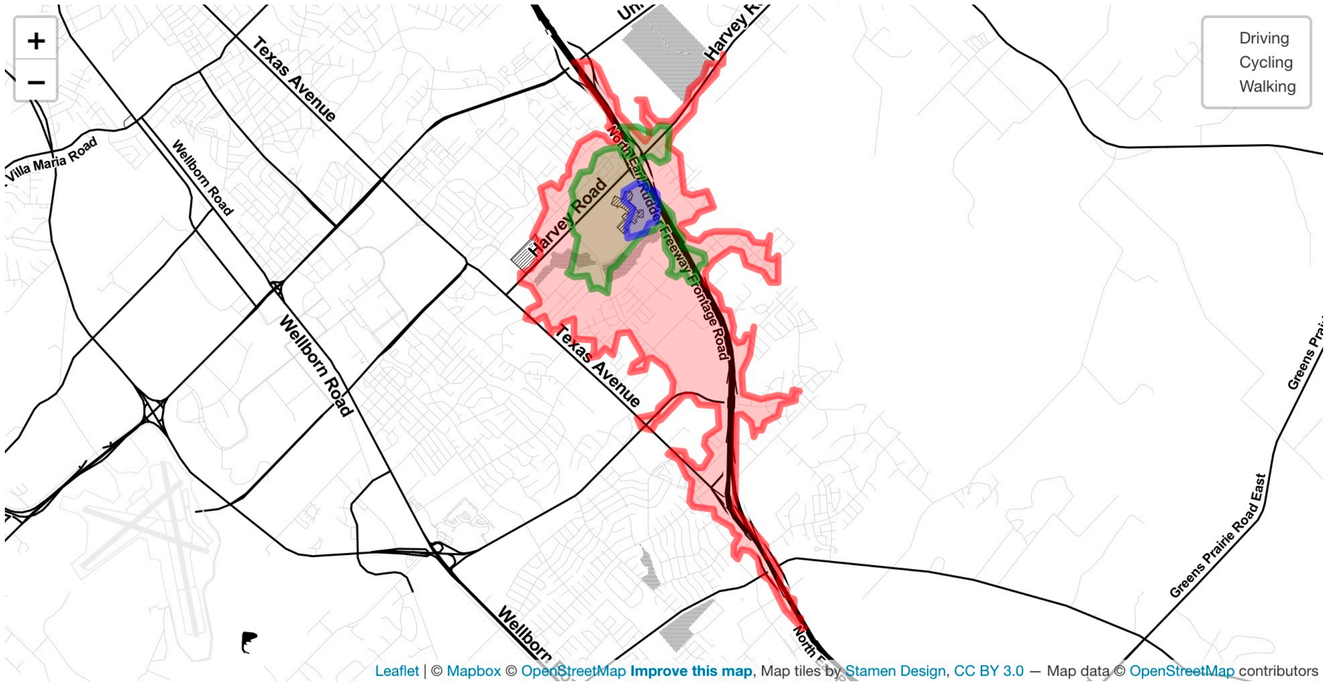
```
leaflet(walk_5min) %>%
   addMapboxTiles(style_id = "streets-v11",
                  username = "mapbox") %>%
   addPolygons()
```



Walking, cycling, and driving time-distances

Step 6: a more complex interactive Leaflet map

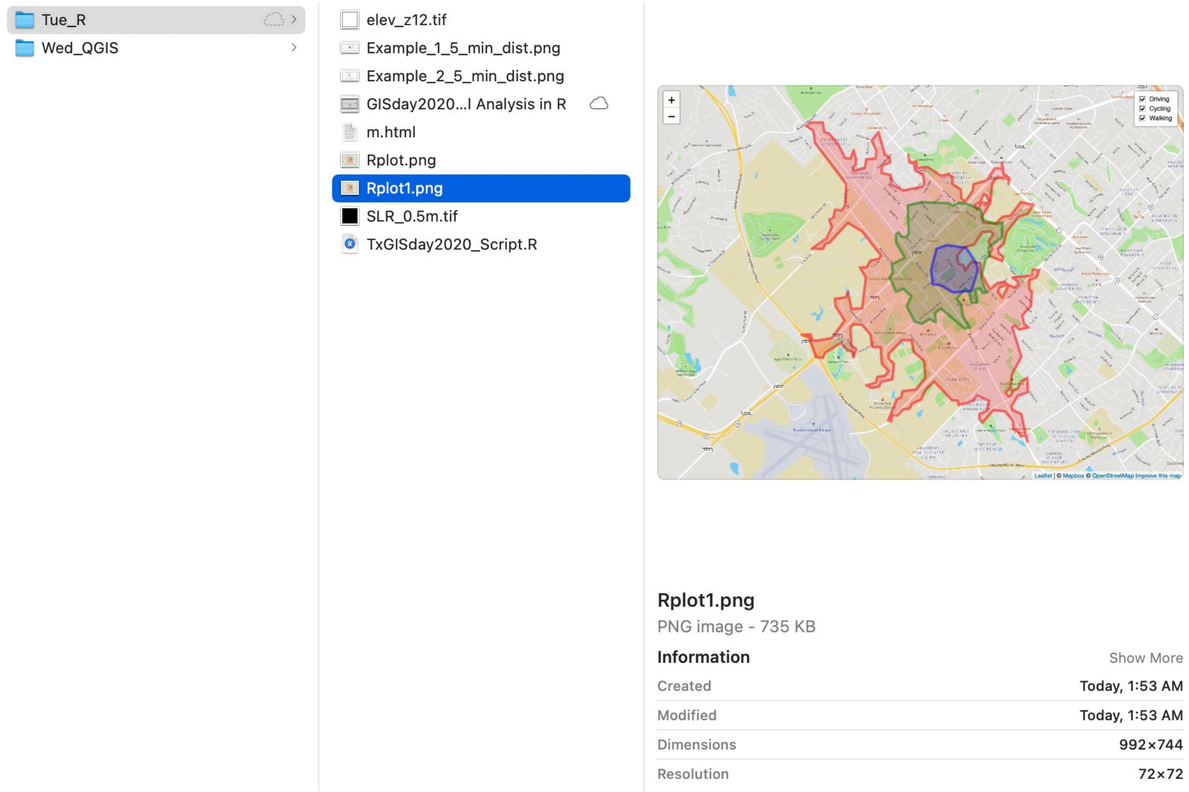
```
leaflet() %>%
   addMapboxTiles(style_id = "streets-v11",
                  username = "mapbox") %>%
   addProviderTiles(providers$Stamen) %>% # Stamen Stamen.Toner Stamen.TonerHybrid OpenTopoMap Esri.WorldImagery
   addPolygons(data = drive_5min, color = "red", group = "Driving") %>%
   addPolygons(data = bike_5min, color = "green", group = "Cycling") %>%
   addPolygons(data = walk_5min, color = "blue", group = "Walking") %>%
   addLayersControl(overlayGroups = c("Driving", "Cycling", "Walking"),
                    options = layersControlOptions(collapsed = FALSE)) # -> m
```



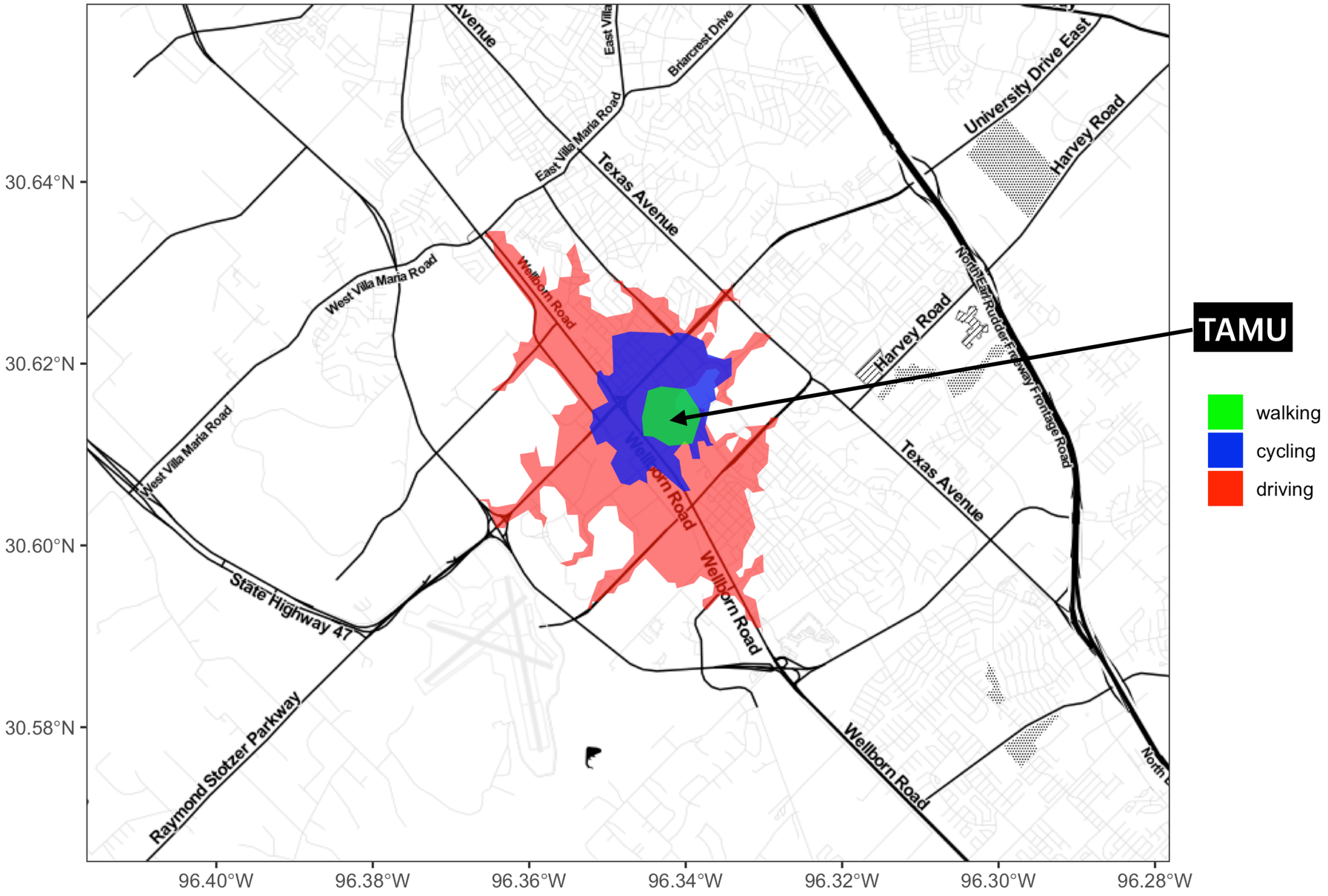
Walking, cycling, and driving time-distances

Step 7: save it

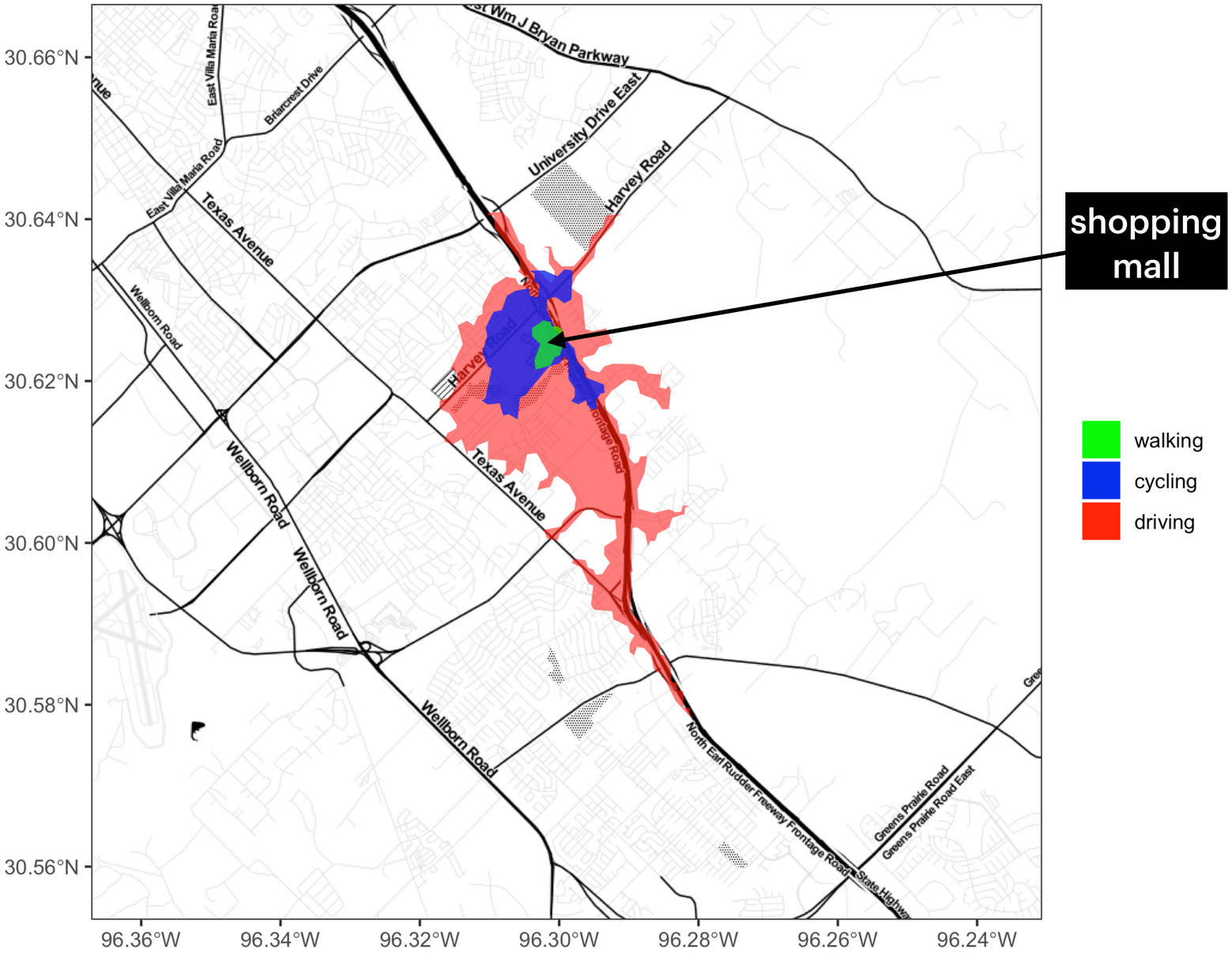
```
library(htmlwidgets)
saveWidget(m, file="m.html")

library(webshot)
webshot("m.html", file = "Rplot1.png", cliprect = "viewport")
```

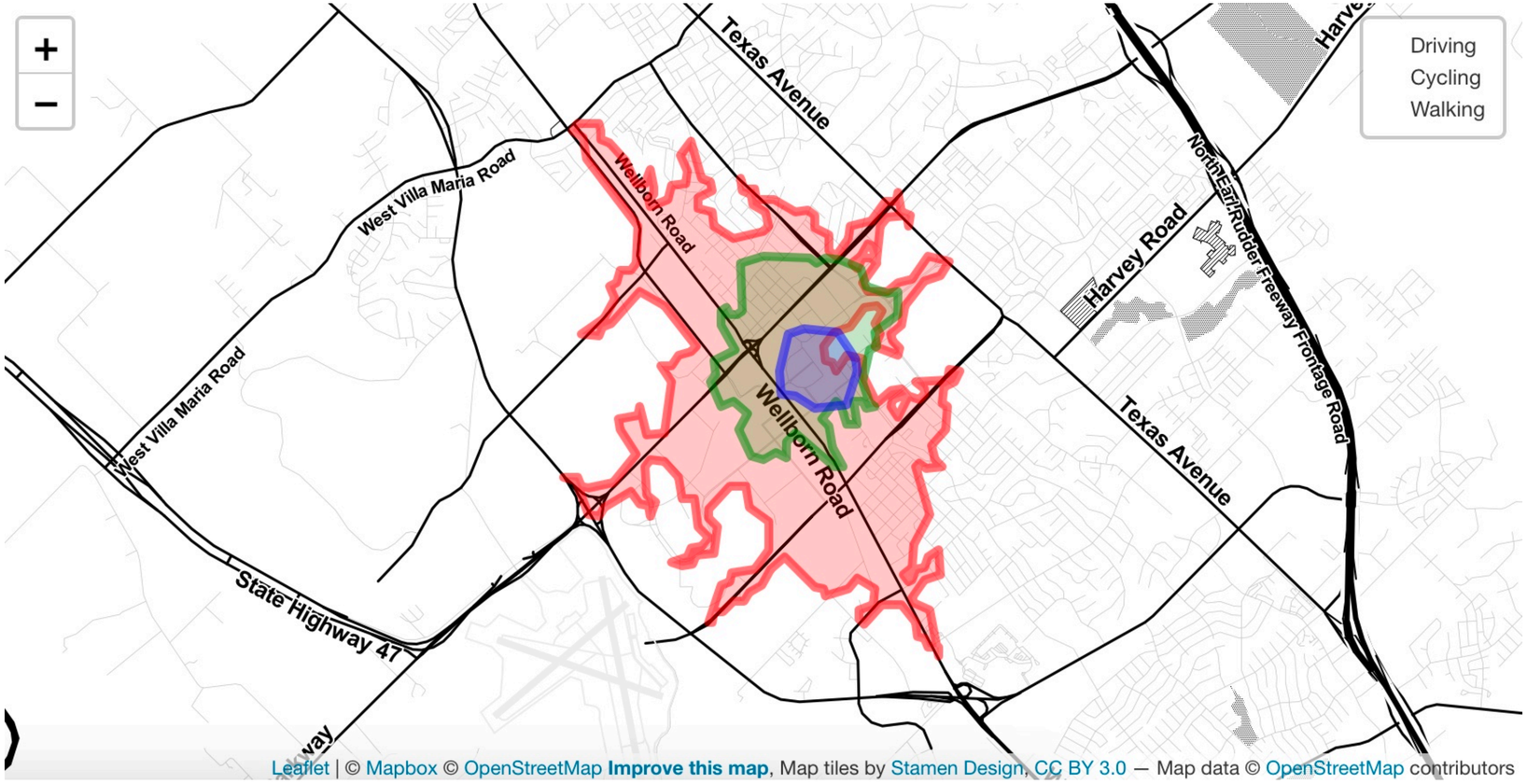


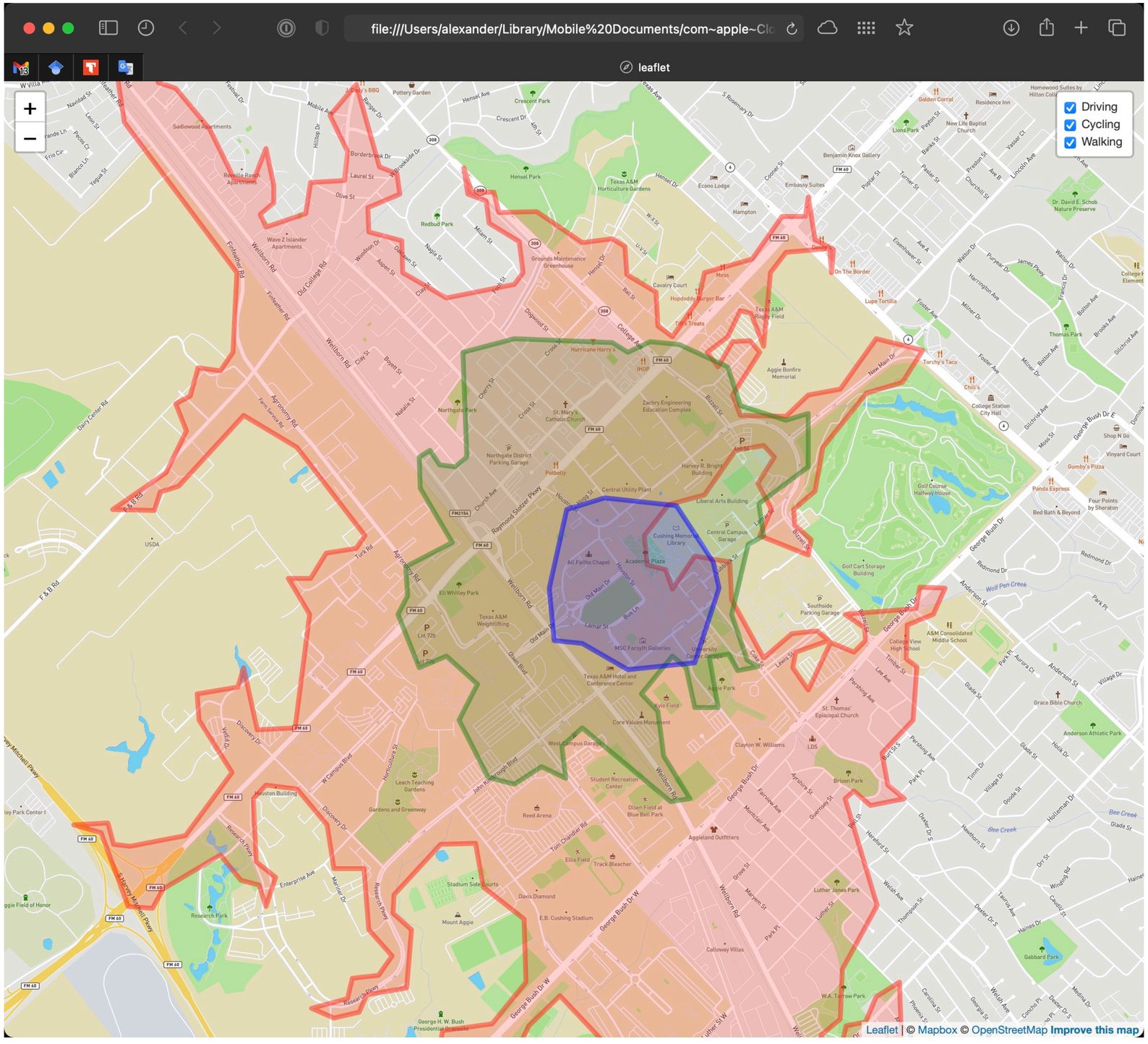
5-minute time-distances



5-minute time-distances




Driving
Cycling
Walking
Texas Avenue
West Villa Maria Road
Wellborn Road
Harvey Road
Northeast Rudder Freeway Frontage Road
State Highway 47
Leaflet | © Mapbox © OpenStreetMap Improve this map, Map tiles by Stamen Design, CC BY 3.0 — Map data © OpenStreetMap contributors


file:///Users/alexander/Library/Mobile%20Documents/com~apple~Clo
leaflet
Driving
Cycling
Walking
Leaflet | © Mapbox © OpenStreetMap Improve this map

Elevation analysis

Additional stuff

Elevation analysis

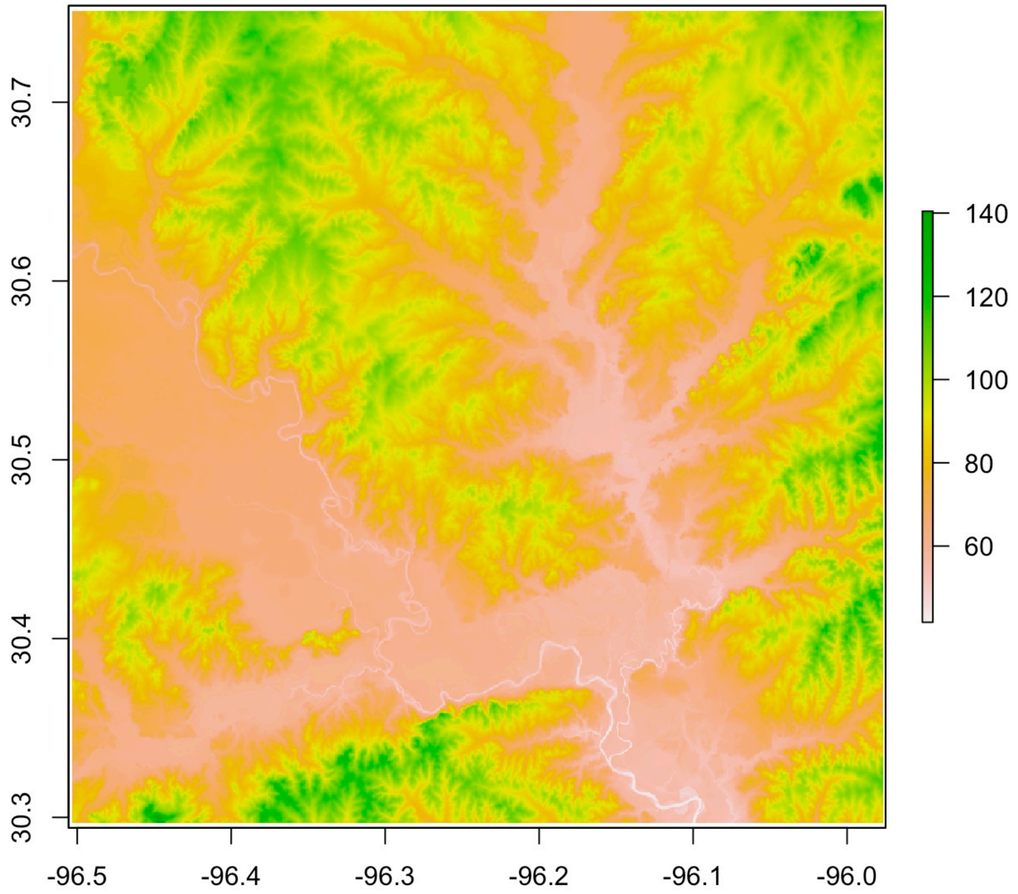
Step 1: Load packages, and define a projection and boundary box

```
if(!require(pacman)){install.packages("pacman"); library(pacman)}
p_load(dplyr, elevatr, haven, lwgeom, maps, raster, rgdal, rgeos,
sf, sp, tigris)

bbox

aux <- as.numeric(bbox)
e <- as(raster::extent(aux[1], aux[3], aux[2], aux[4]), "SpatialPolygons")
proj4string(e) <- st_crs(drive_5min)$proj4string
# proj4string(e) <- CRS("+proj=utm +zone=10 +datum=WGS84")
```

Elevation analysis

Step 2: Get elevation (or just load it)

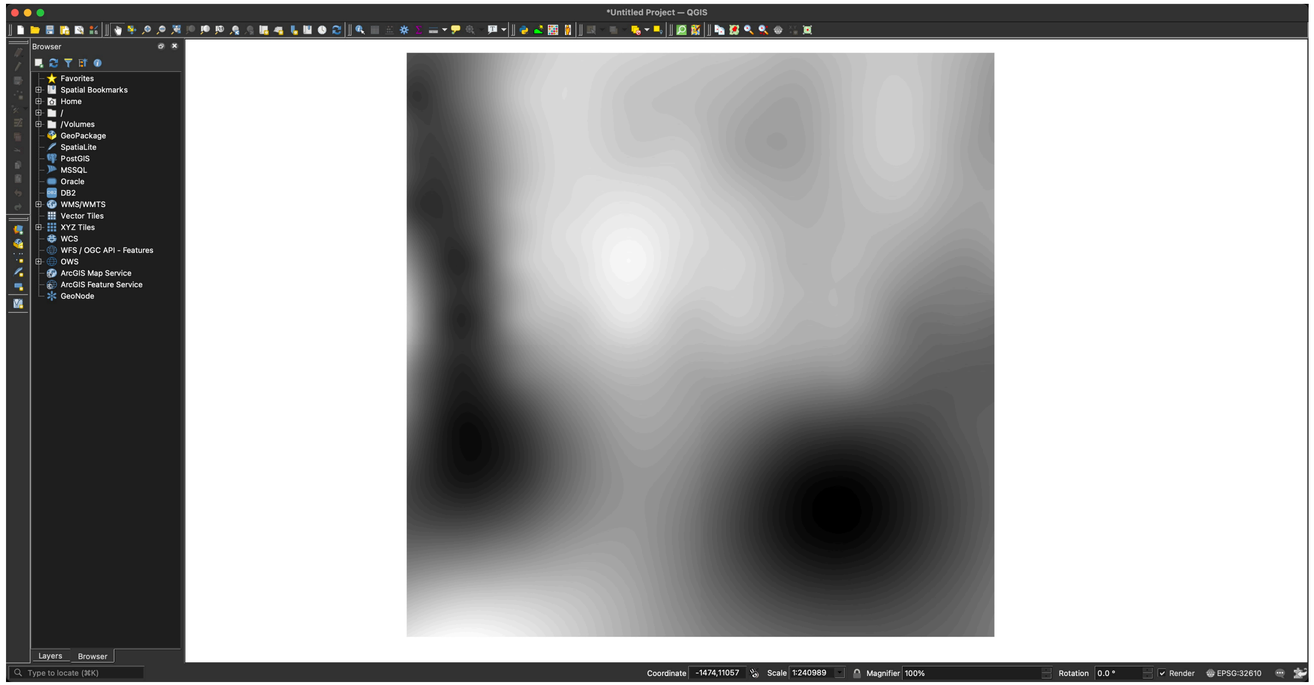
```
x <- get_elev_raster(e, prj=sp::proj4string(e), z=11, src="aws") # 1 to 14
x <- raster("elev_z12.tif", format="GTiff")
plot(x)
```

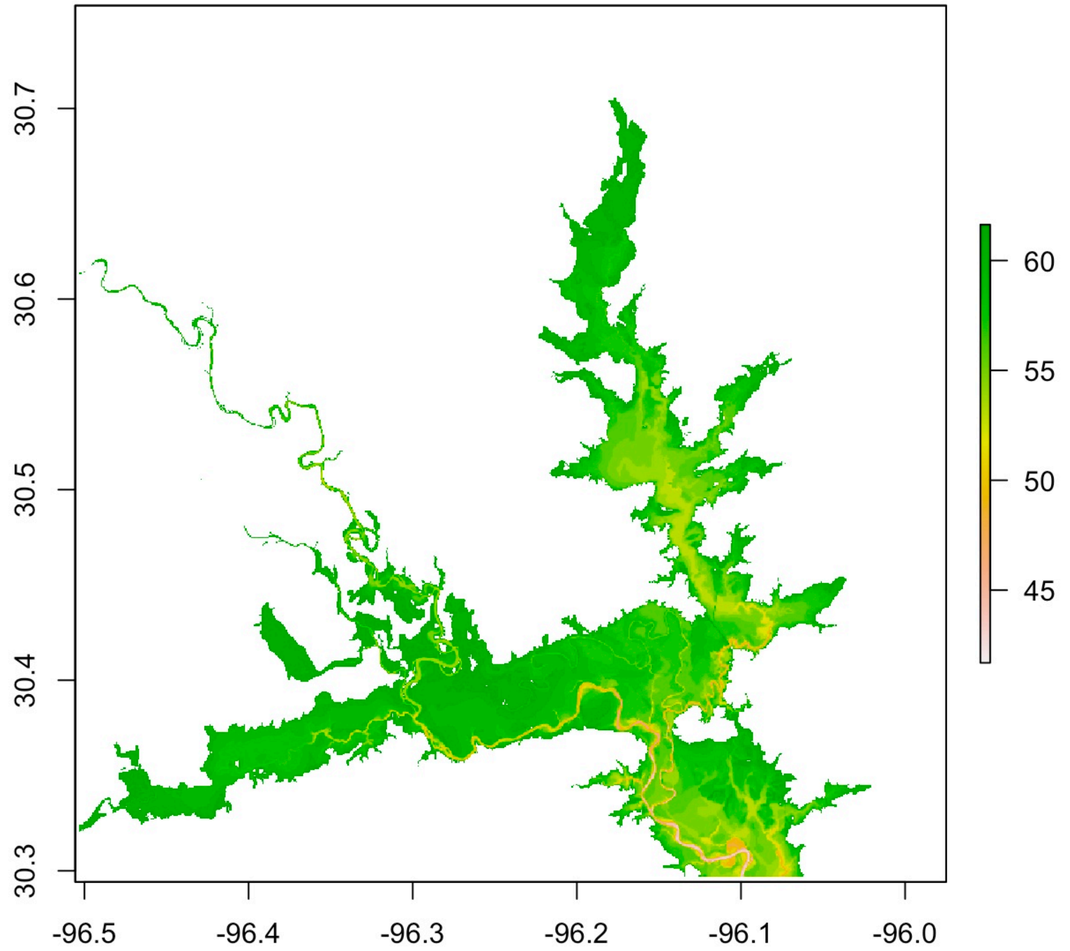


Elevation analysis

Step 3: 20 m elevation mask

```
min_value <- minValue(x)
maxValue(x)

x2 <- x

x2[x2 <= min_value] <- NA; x2[x2 >= (min_value + 20)] <- NA
plot(x2)

writeRaster(x, filename="elev_z12.tif", format="GTiff", overwrite=T)
```

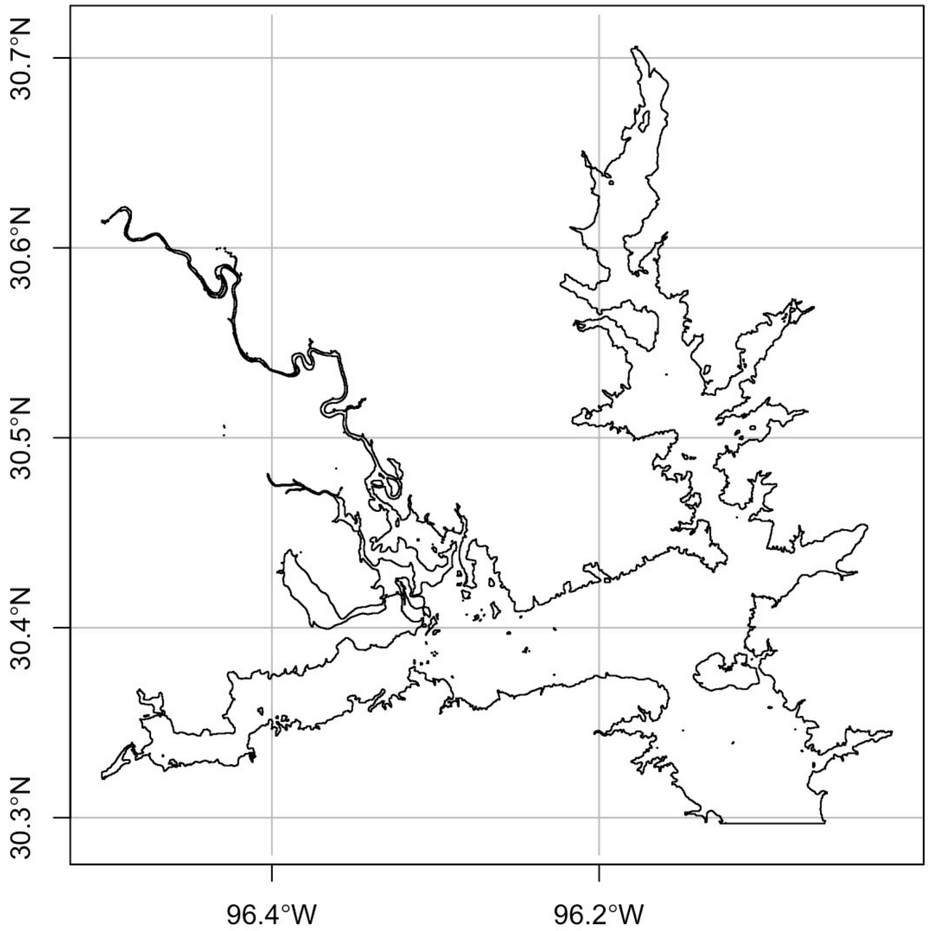




Elevation analysis

Step 4: 20 m elevation polygonized

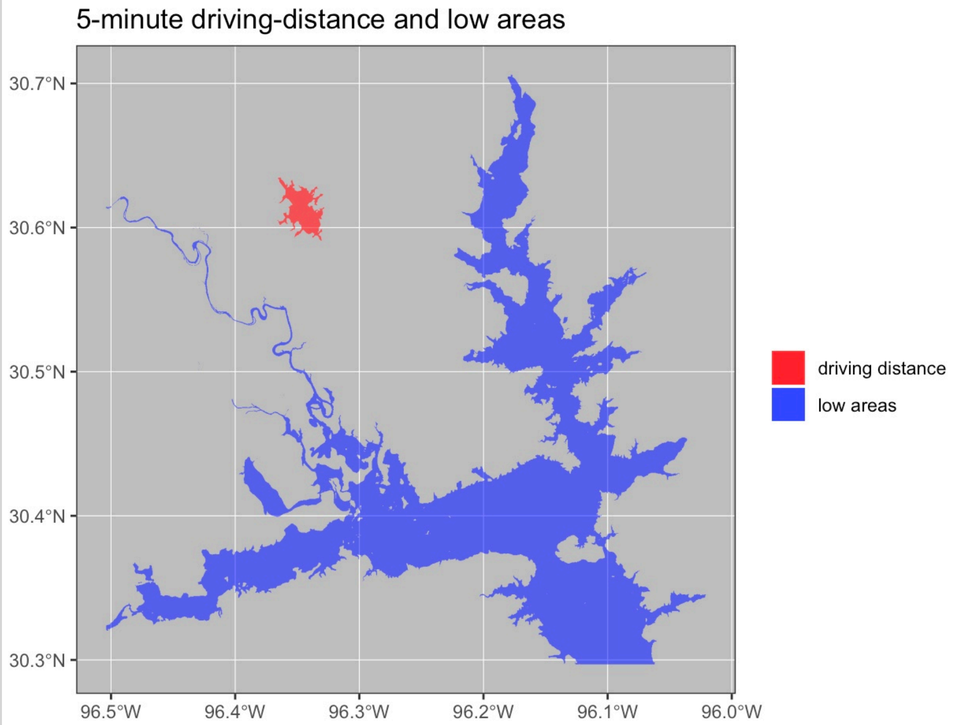
```
x2_poly <- spex::polygonize(x2) %>%
   group_by() %>%
   st_union() %>%
   st_make_valid()

st_area(x2_poly)


plot(st_geometry(x2_poly), graticule=TRUE, axes=TRUE)
```



Elevation analysis

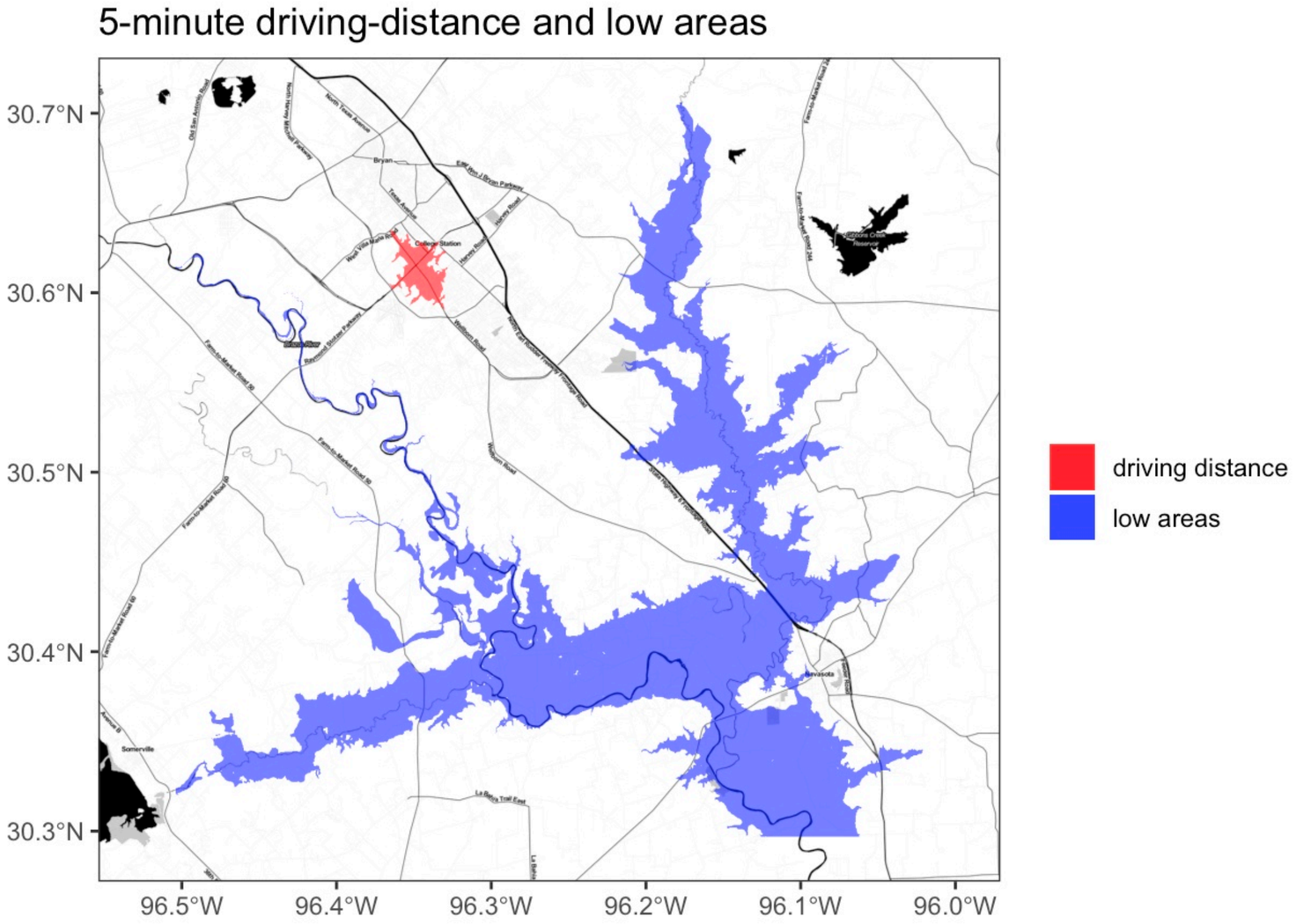
Step 5: Plot

```
bbox = c(left = as.numeric(st_bbox(x2_poly)$xmin-0.05),
         bottom = as.numeric(st_bbox(x2_poly)$ymin-0.025),
         right = as.numeric(st_bbox(x2_poly)$xmax+0.05),
         top = as.numeric(st_bbox(x2_poly)$ymax+0.025))

map <- get_stamenmap(bbox,
                     maptype = "toner-2011",
                     zoom = 12)

ggplot() +
   # ggmap(map) +
   geom_sf(data = x2_poly,
           aes(fill = "low areas"),
           color = "white", alpha = 0.6, linetype = "blank",
           show.legend = TRUE, inherit.aes = FALSE) +
   geom_sf(data = drive_5min,
           aes(fill = "driving distance"),
           color = "white", alpha = 0.6, linetype = "blank",
           show.legend = TRUE, inherit.aes = FALSE) +
   scale_fill_manual(values = c("driving distance" = "red",
                                "low areas" = "blue"),
                     breaks =  c("driving distance", "low areas")) +
   labs(x="", y="", title="5-minute driving-distance and low areas", fill="") +
   theme(legend.justification="left",
         panel.background=element_rect(fill="grey", colour="grey",
         size=0.5, linetype="solid"),
         panel.grid.major=element_line(size=0.2, linetype="solid", colour="white"),
         panel.grid.minor=element_line(size=0.2, linetype="solid", colour="white"))
```



Elevation analysis

Step 6: 20 m elevation polygonized



Thank you!

COLLEGE OF ARCHITECTURE

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