Density Maps

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Introduction

Sometimes Dot maps can have **overlapped points** that difficult the visualization of more specific patterns. Additionally, most times spatial data requires *more explicit* Google Maps-like **geographic context**.

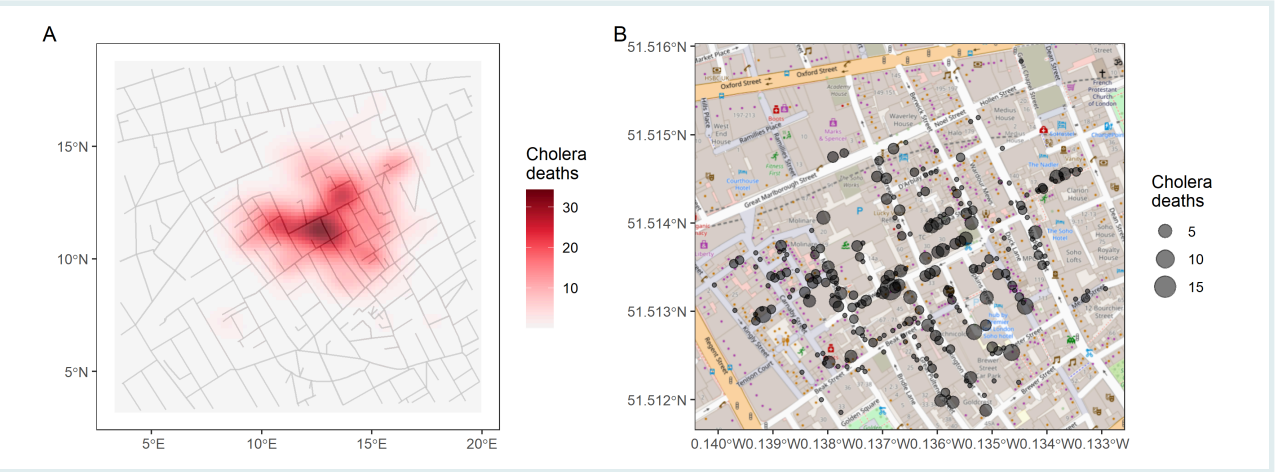


Figure 1. (A) John Snow's Density map. (B) John Snow's Dot map complemented with the city street roads.

In this lesson, we are going to learn about how use *Density maps* to avoid overlaps in them, and how to add *Basemaps* for Google Maps-like backgrounds.

Learning objectives

1. Identify one more type of Thematic map (**Density maps**) used by epidemiologist to visualize *overlapping* Geospatial data.

2. Complement *Thematic maps* with **Basemaps** for Google Maps-like backgrounds using the `annotation_map_tile()` function, from the `{ggspatial}` package.

Prerequisites

This lesson requires the following packages:

```
if(!require('pacman')) install.packages('pacman')
pacman::p_load_gh("afrimapr/afrilearndata")
pacman::p_load_gh("avallecam/epihelper")
pacman::p_load(ggspatial,
               ggplot2,
               tibble,
               terra,
               dplyr,
               spData,
               sf,
               prettymapr)
```

This lesson requires familiarity with `{ggplot2}`: if you need to brush up, have a look at our introductory course on data visualization.

Density map

What is it?

A *Density map* is a type of Thematic map where colours are used to represent intensity of a value, however, it does not use defined regions or geopolitical boundaries to group data. This type of map is typically used for showing **'hot spots'** or areas with a high density or concentration of points.

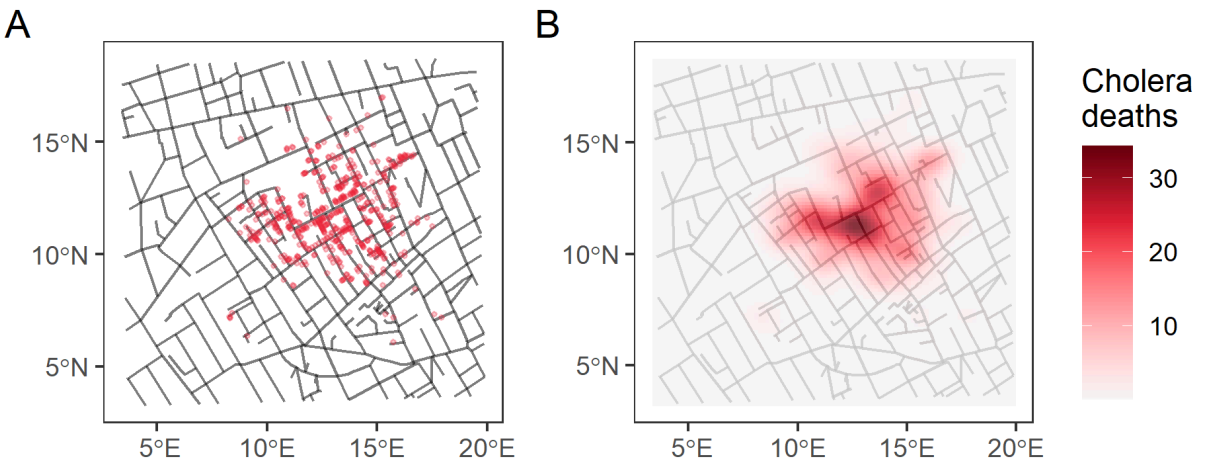


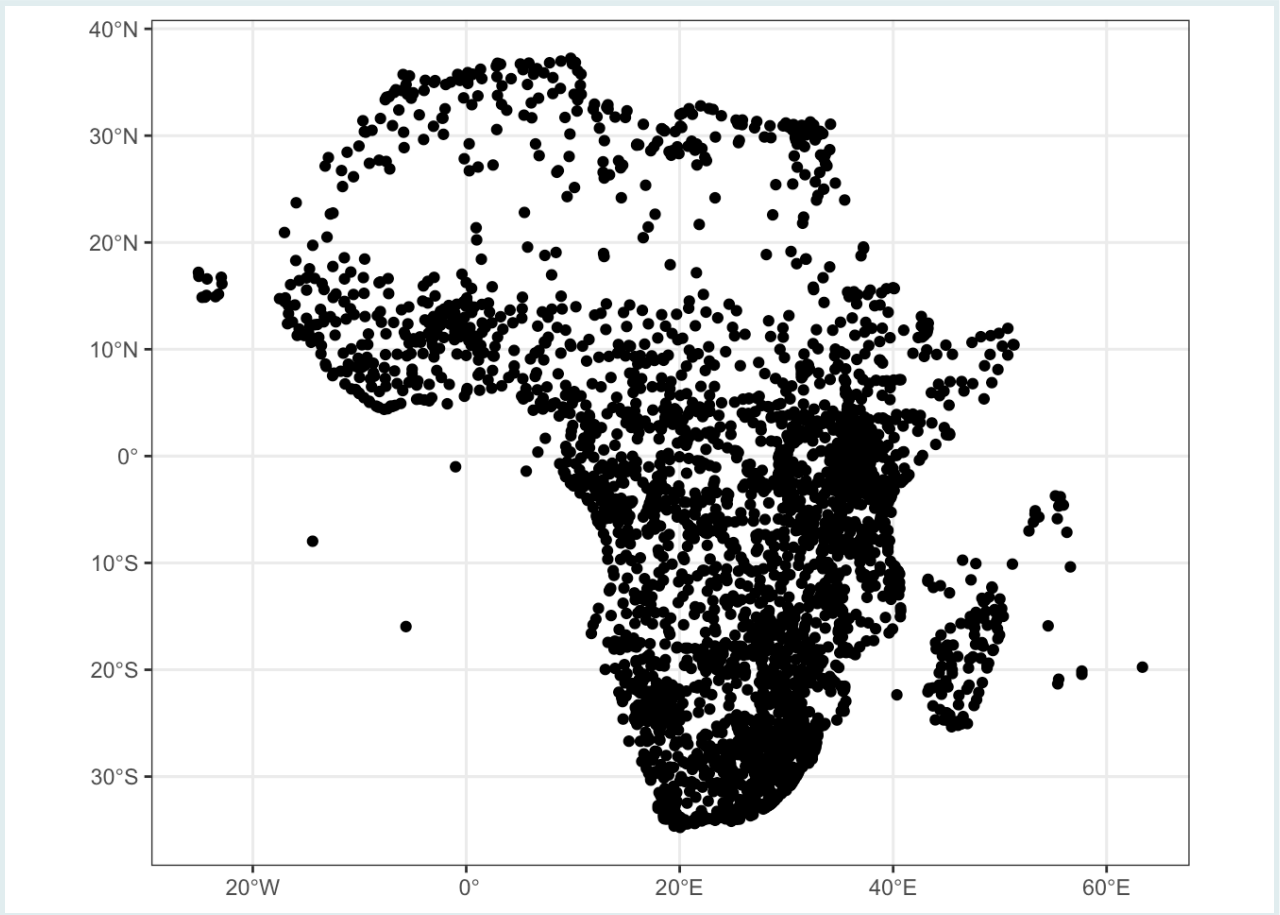
Figure 4. (A). John Snow's Dot distribution map with overlapping Point pattern data. (B) Density map from John Snow's Dot distribution map Point pattern data.

How to plot it?

As an example, we are going to use the `afriairports` dataset, from the `{afrilearndata}` package, that contains the locations of African airports.

With a Dot map we get *overlapping points* using the `geom_sf()` function, as in here:

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



A *Density map* with `{ggplot2}` will require **four main steps**. Let's use the `afriairports` dataset as an example:

1. First, use `epihelper::st_coordinates_tidy()` to *retrieve* the point coordinates.
2. Then, use the `ggplot()` function to define the *new* coordinates column names X and Y,
3. Use the `geom_bin_2d()` function to depict the *number of airports per area*,
4. Lastly, use the `coord_sf()` function to *transform* the figure **X** and **Y** axis:
    - fix their aspect ratio and
    - add a coordinate reference system format (for instance, from 30°S to 40°N in the **Y** axis).

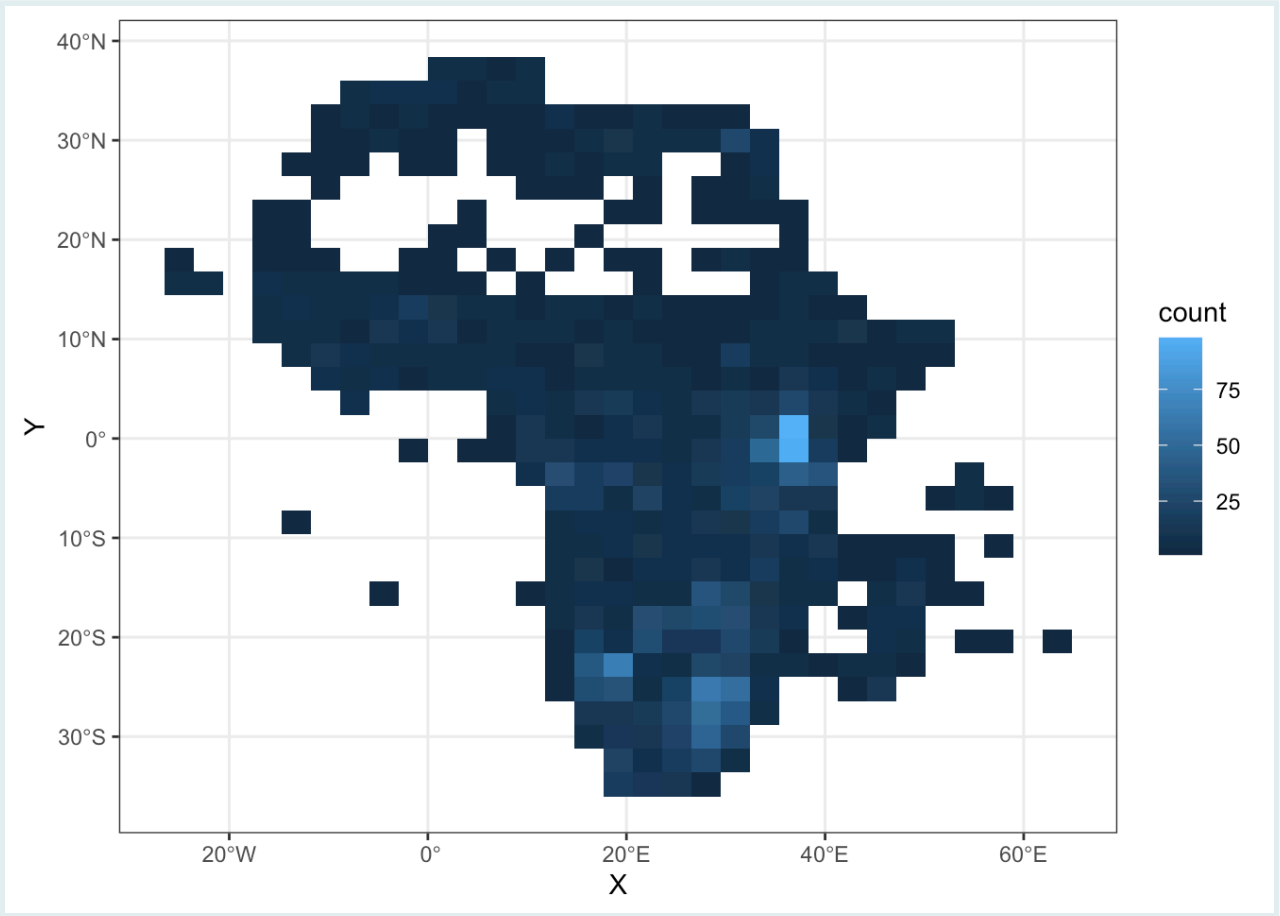
```
afriairports %>%

  # 👉 (1) extract coordinates
  st_coordinates_tidy() %>%

  # 👉 (2) define new coordinates with ggplot()
  ggplot(aes(x = X, y = Y)) +

  # 👉 (3) with a new geom function
  geom_bin_2d() +

  # 👉 (4) transform axis
  coord_sf()
```



Create a Density map with the `pcrime` data read from the `pcrime.rds` local file.

```
pcrime <- read_rds(here("data/pcrime.rds"))
```

```
pcrime
```

Use the `geom_bin_2d()`, to portrait the number of crimes per area, faceted by the two types of crime in the column `marks`.

```
pcrime %>%
  st_coordinates_tidy() %>%
  ggplot(aes(x = X,y = Y)) +
  .........() +
  coord_sf() +
  facet_wrap(~marks)
```

How to use it?

This type of Thematic map is best used with *Environmental data*, such as altitude, air pollution or rainfall data values measured at several monitoring stations.

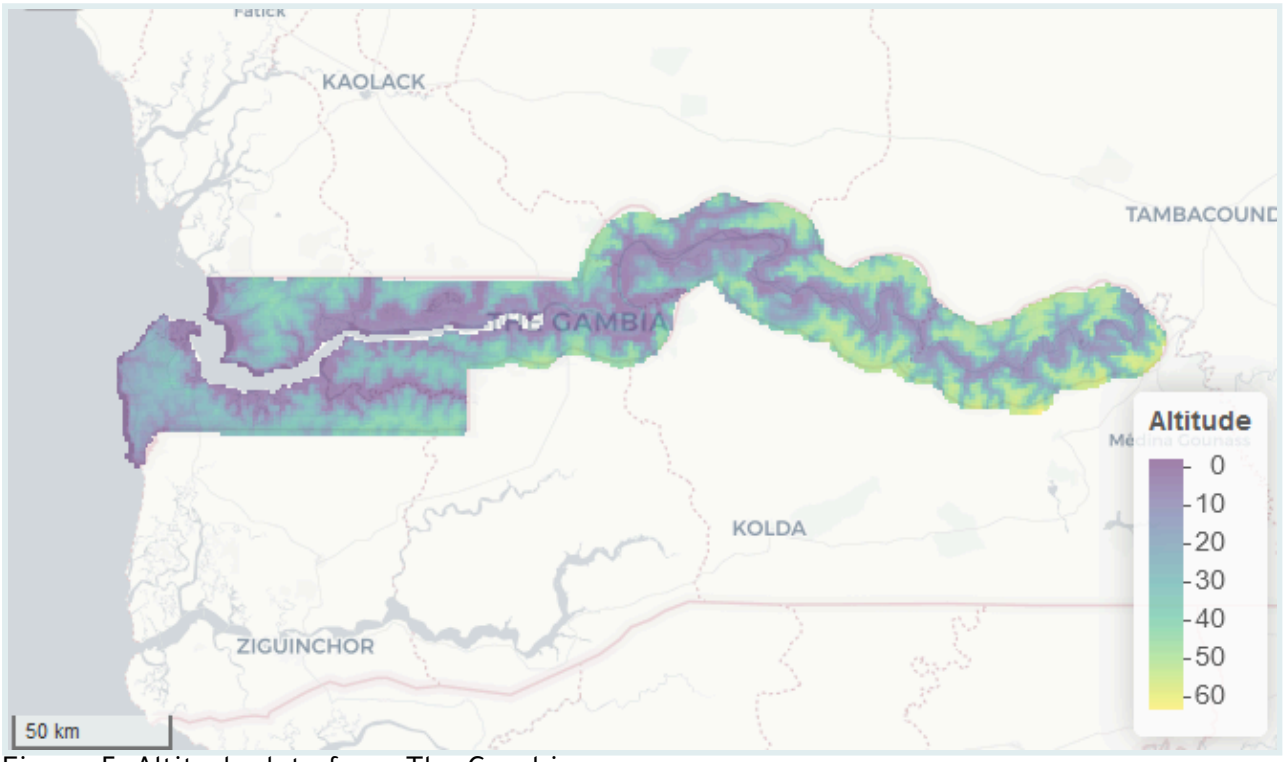


Figure 5. Altitude data from The Gambia.

Density maps are also used to visualize *spatially continuous disease prevalence surfaces*. For example, Moraga et al. (2019) used the prevalence values of malaria in children obtained from surveys conducted at 65 villages in The Gambia to predict the *disease prevalence* at *unobserved locations*, using a geostatistical model.

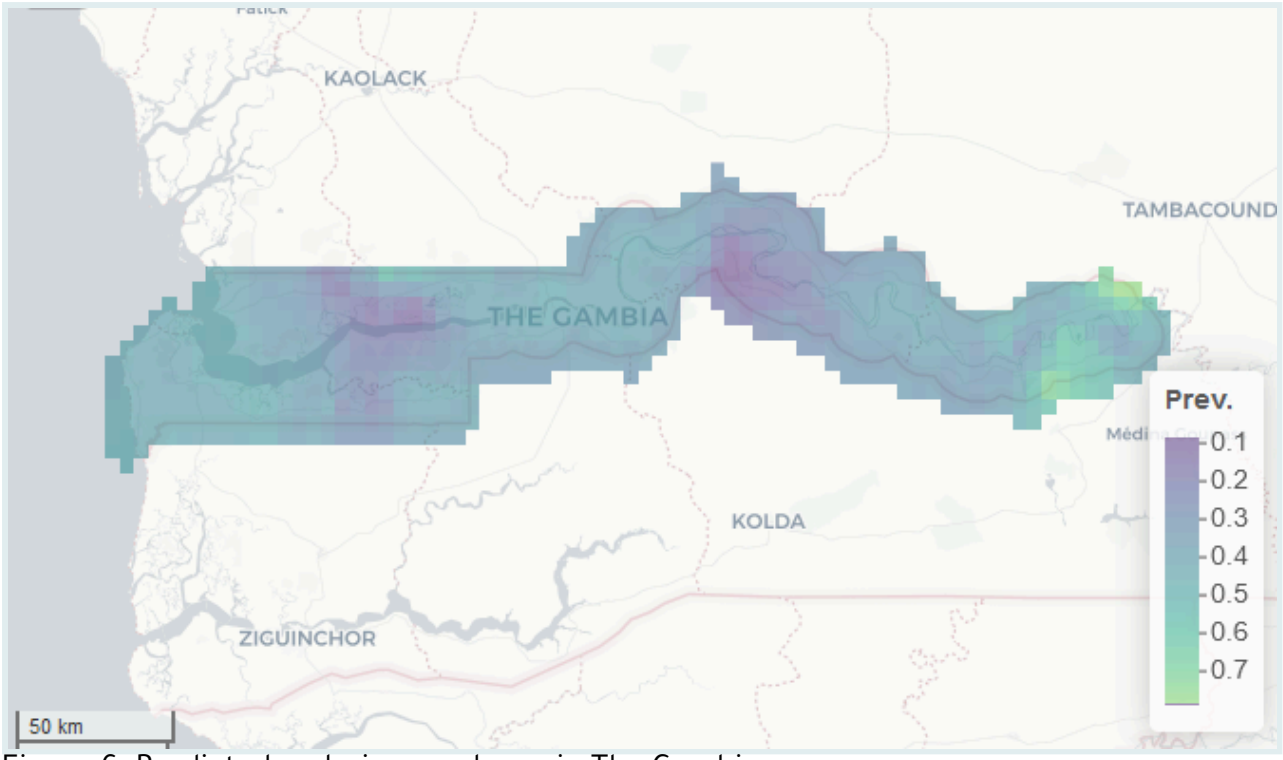


Figure 6. Predicted malaria prevalence in The Gambia.

What alternative plots do we have?

There are two {ggplot2} alternatives to plot Density maps:

In one hand, the `geom_density_2d_filled()` function creates a contoured density plot to identify clusters of `"count"` values:

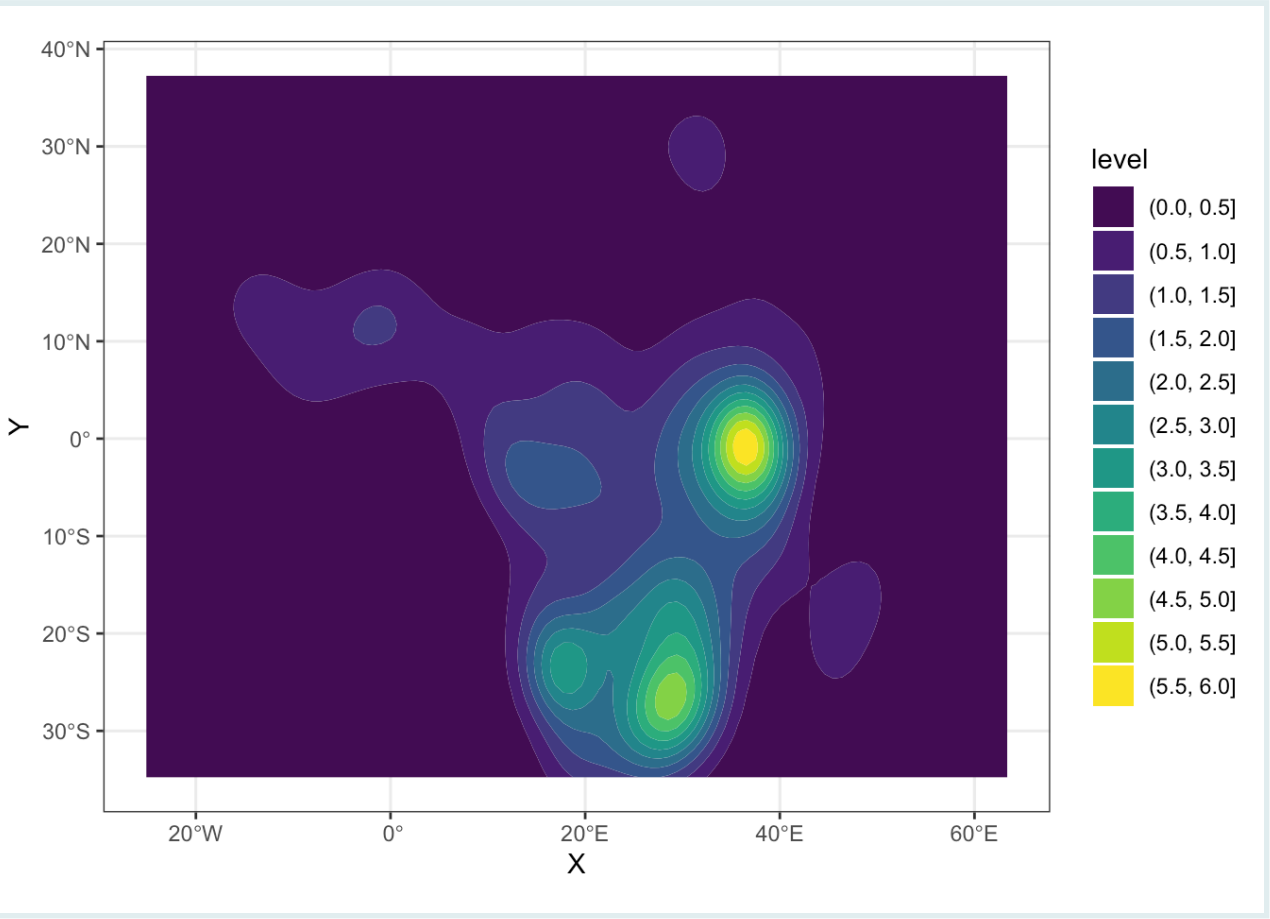
```
afriairports %>%

  # (1) extract coordinates
  st_coordinates_tidy() %>%

  # (2) start ggplot
  ggplot(aes(x = X, y = Y)) +

  # 👉 with an alternative geom function 👈
  geom_density_2d_filled(contour_var = "count") +

  # (4) transform axis
  coord_sf()
```



In the other hand, the `stat_density_2d()` allows to create a continuous surface of counted values from point data:

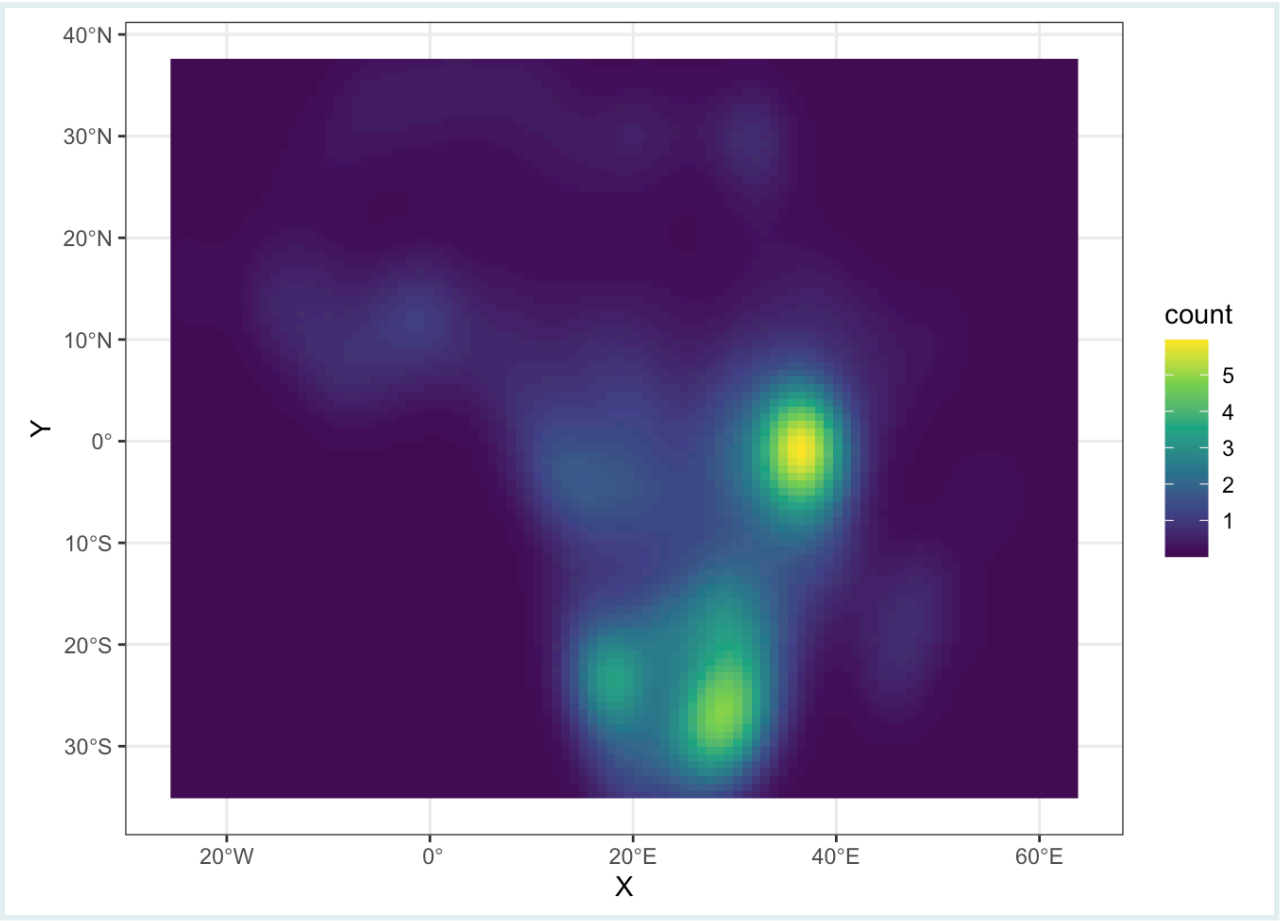
```
afriairports %>%

  # (1) extract coordinates
  st_coordinates_tidy() %>%

  # (2) start ggplot
  ggplot(aes(x = X, y = Y)) +

  # 👉 with an alternative geom function 👈
  stat_density_2d(
    geom = "raster",
    mapping = aes(fill = after_stat(count)),
    contour = FALSE) +
  scale_fill_viridis_c() +

  # (4) transform axis
  coord_sf()
```



Use the `st_coordinates_tidy()` function to extract the X and Y coordinates from the `pcrime` dataset.

This will be useful to built a Density map with `geom_density_2d_filled()` and portrait the number of crimes per area, faceted by the two types of crime in the column `marks`.

```
pcrime %>%
  ..... %>%
  ggplot(aes(x = X,y = Y)) +
  geom_density_2d_filled() +
  coord_sf() +
  facet_wrap(~marks)
```

Basemaps

For all our previous maps, we only have partial context for what we are seeing. For a more integrative view, we may want to overlay our map over *Google Maps-like* physical features. These are called **Basemaps**.

In a Dot map

For example, for our London cholera outbreak Dot map, we want to overlay it on the London street map—and this is exactly what `{ggspatial}` lets us do.

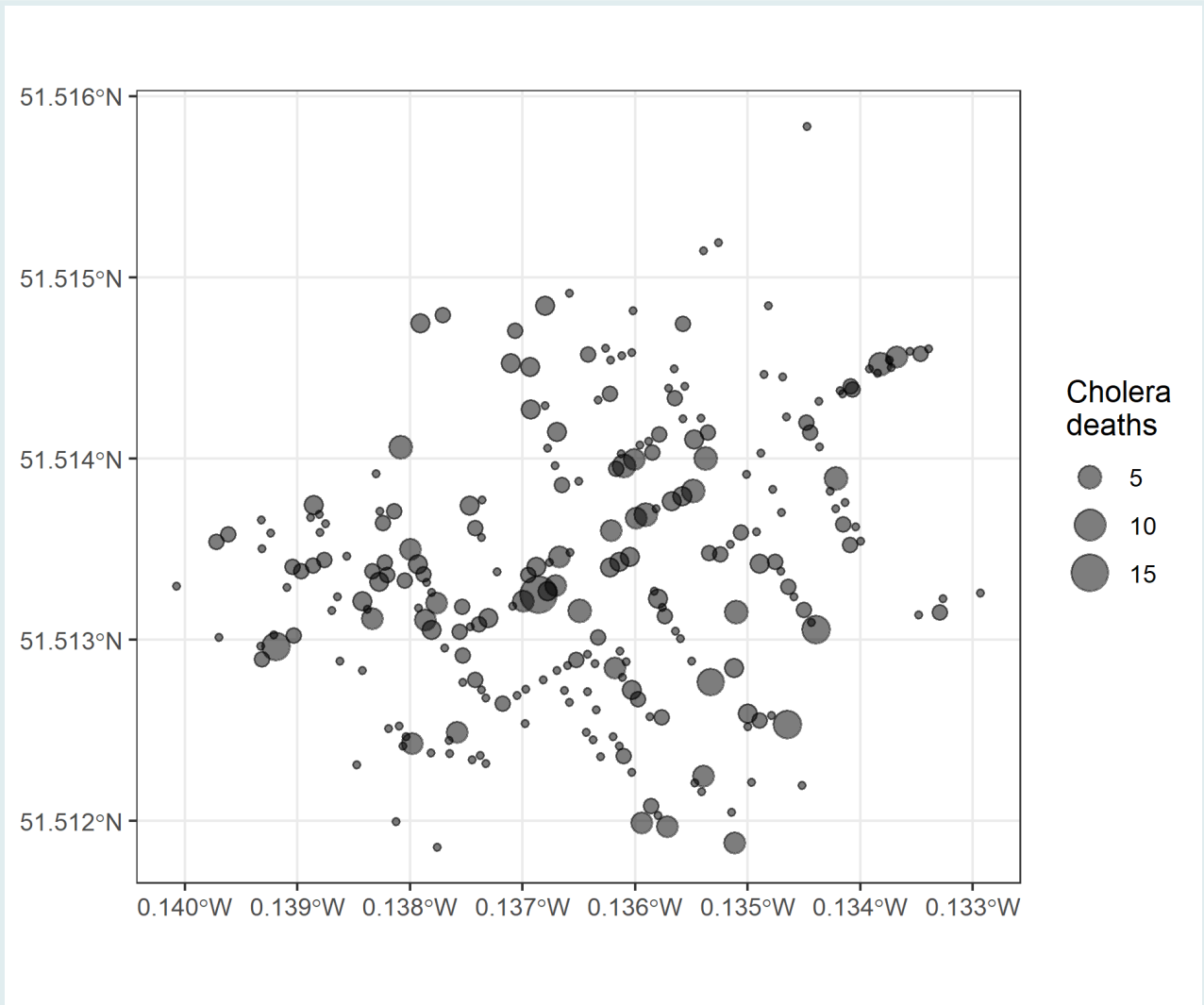


Figure 7. John Snow's Dot map.

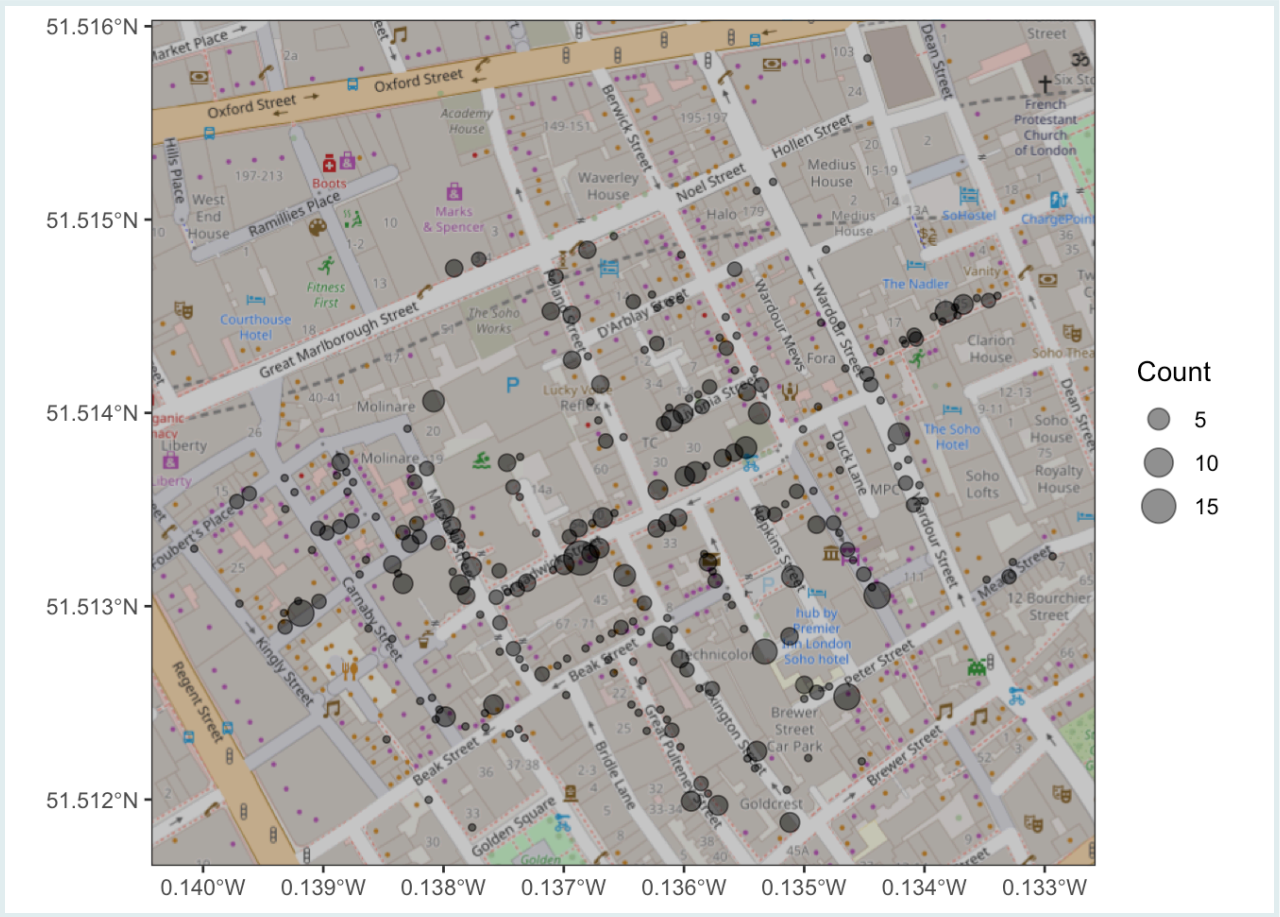
The `annotation_map_tile()` function adds a layer of **map tiles** pulled from Open Street Map. We can control the `zoom` level. Here, we map the number of deaths at each location to the size of the dot.

```
cholera_deaths <- read_rds(here("data/cholera_deaths.rds"))

ggplot(data = cholera_deaths) +

  # 👉 add a basemap 👈
  annotation_map_tile(zoomin = 0) +

  # continue with ggplot
  geom_sf(mapping = aes(size = Count), alpha = 0.5)
```



Add a Basemap to a Dot map using the `africapitals` object and the `annotation_map_tile()` function.

```
ggplot(data = africapitals) +
  .......() +
  geom_sf(mapping = aes(size = pop), alpha = 0.5)
```

In a Density map

Add a Basemap to a Density map using the `pcrime` object and the `annotation_map_tile()` function.

```
pcrime %>%

  # (1) extract coordinates
  st_coordinates_tidy() %>%

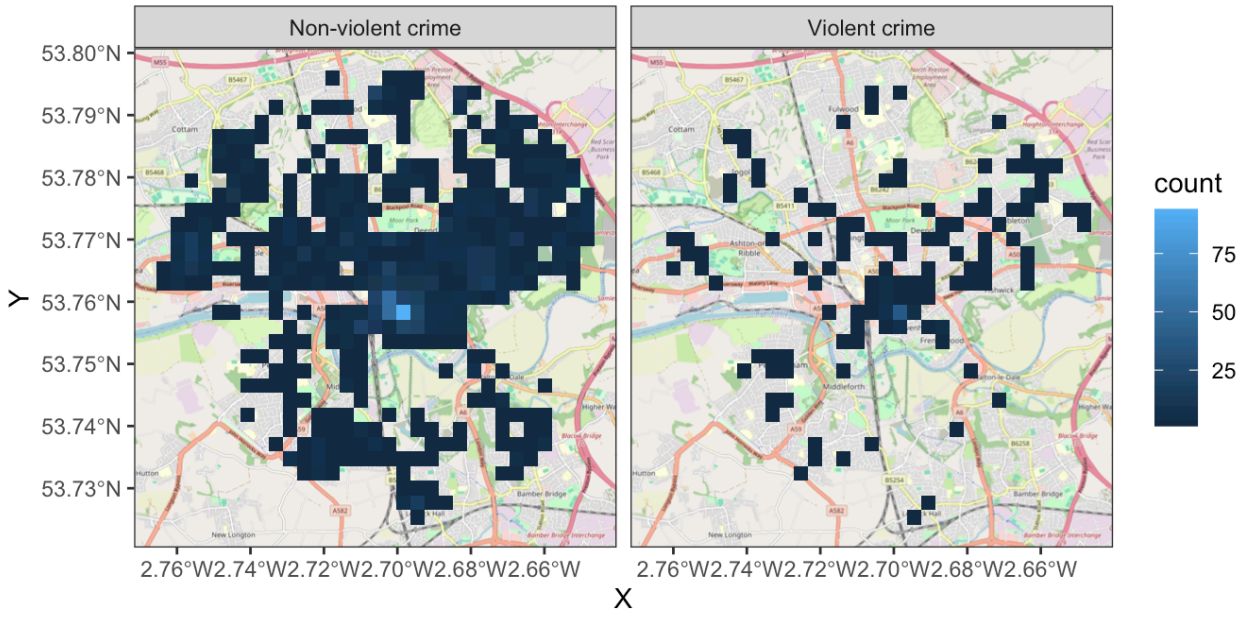
  # (2) start ggplot
  ggplot(aes(x = X, y = Y)) +

  # 👉 add a basemap 👈
  annotation_map_tile(zoomin = 0) +

  # (3) with a new geom function
  geom_bin_2d() +

  # (4) transform axis
  coord_sf() +

  # facet
  facet_wrap(~marks)
```

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```

WATCH OUT

- The basemap must be bellow the `geom_*` function!

Use two functions, `annotation_map_tile()` and `geom_bin_2d()`, to add a Basemap to a Density map using the `afriairports` object.

```
afriairports %>%
  st_coordinates_tidy() %>%
  ggplot(aes(x = X, y = Y)) +
  ............() +
  ............() +
  coord_sf()
```

Wrap up

In this lesson, we have learned about one more type of Thematic map called *Density maps* to avoid overlapping spatial points. Also, how to add Google Maps-like backgrounds called *Basemaps*.

But, How can we create more *Thematic maps* from **external** Spatial data created by other GIS software? In the following lessons, we are going to learn how to **read external Spatial data** and *convert foreign* objects to *sf* files! Follow along with the lessons to find how to train these skills!

Answer Key

Practice 1

```
pcrime %>%
    @@ -366,7 +352,7 @@ pcrime %>%
    facet_wrap(~marks)
```

```
## Error: <text>:2:9: unexpected '@'
## 1: pcrime %>%
## 2:         @
##            ^
```

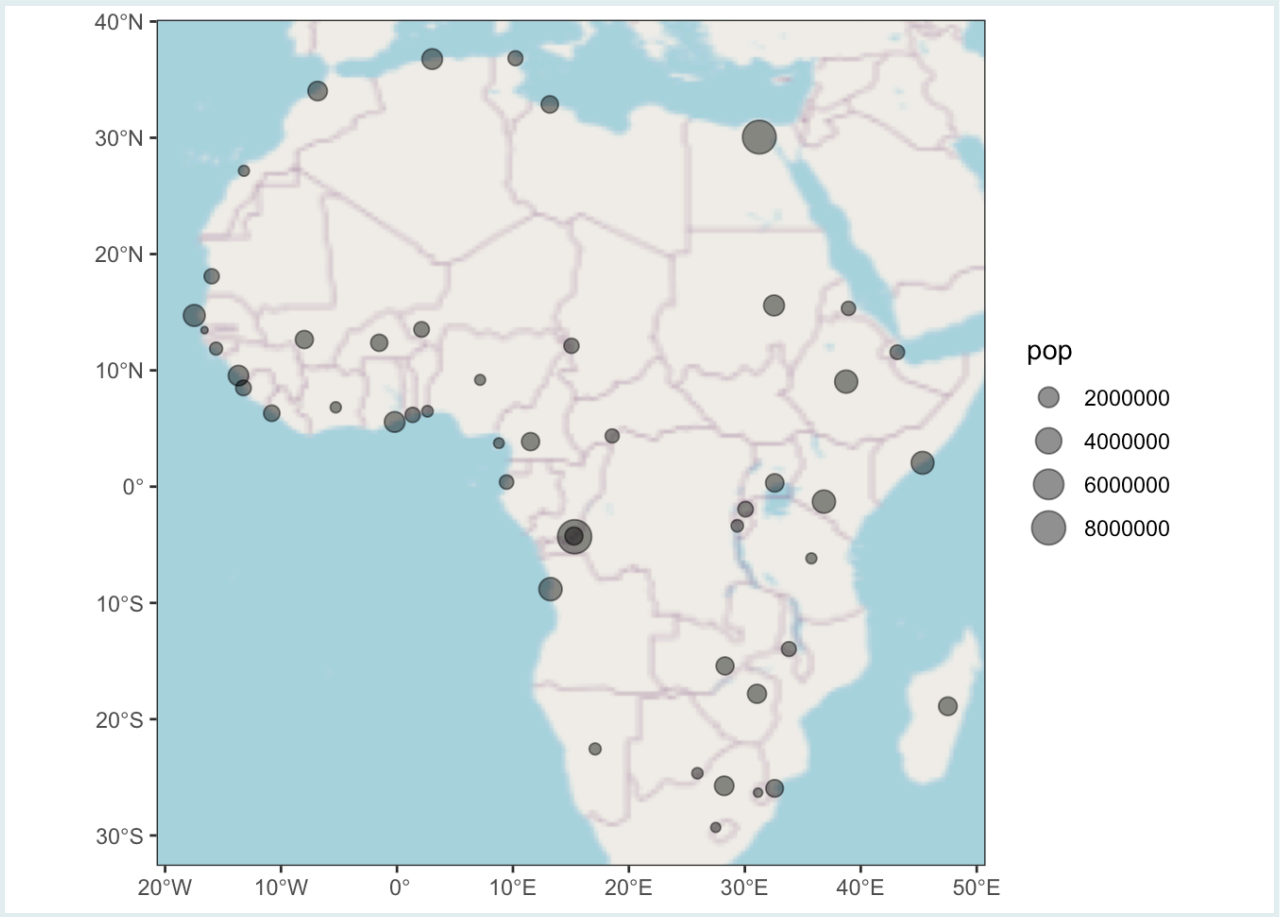
Practice 2

```
pcrime %>%
    @@ -377,15 +363,15 @@ pcrime %>%
    facet_wrap(~marks)
```

```
## Error: <text>:2:9: unexpected '@'
## 1: pcrime %>%
## 2:         @
##            ^
```

Practice 3

```
ggplot(data = africapitals) +
    annotation_map_tile() +
    geom_sf(mapping = aes(size = pop), alpha = 0.5)
```




```
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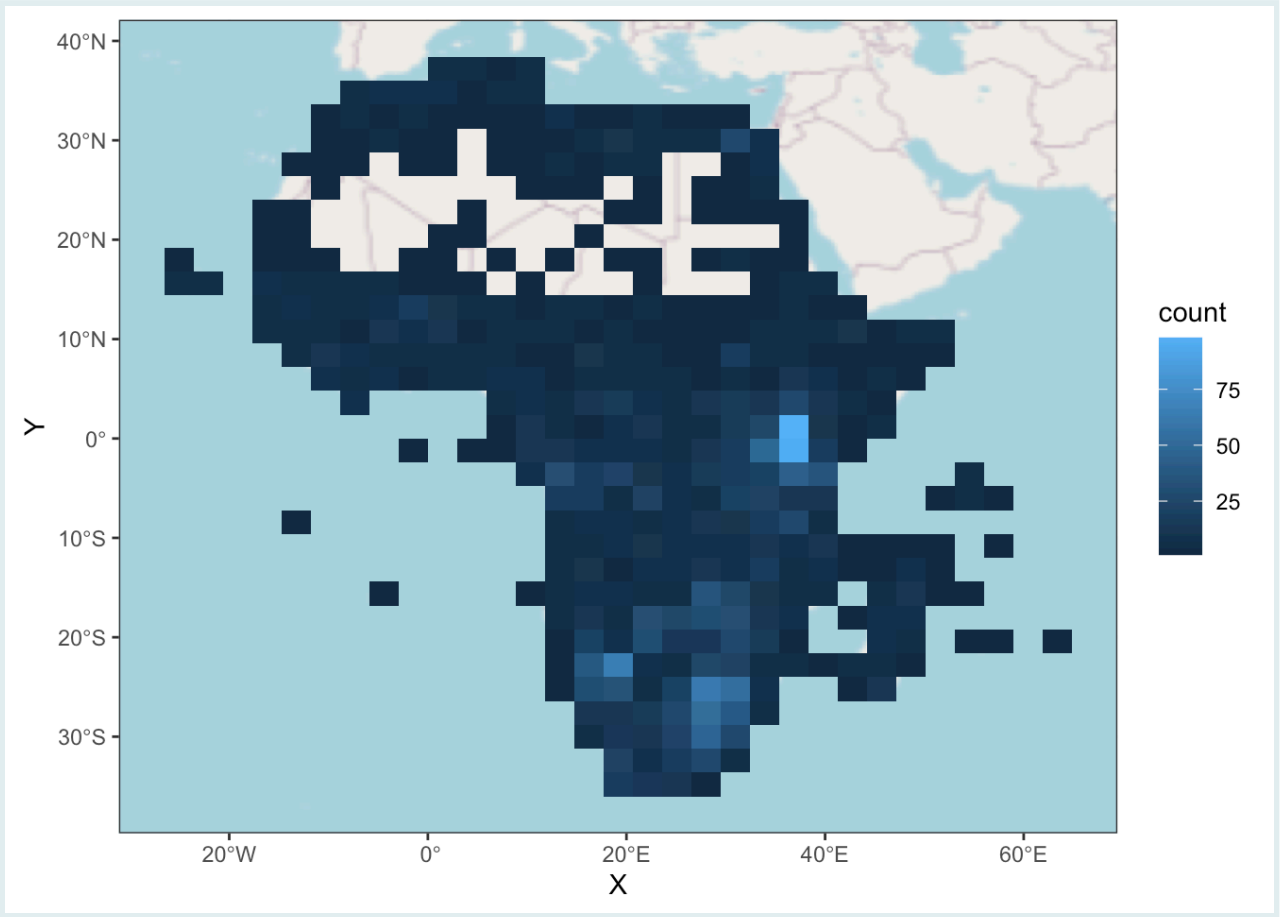
```

Practice 4

```
afriairports %>%
    epihelper::st_coordinates_tidy() %>%
    ggplot(aes(x = X, y = Y)) +
    annotation_map_tile() +
    geom_bin_2d() +
    coord_sf()
```



Contributors

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References

Some material in this lesson was adapted from the following sources:

- *Batra, Neale, et al. (2021). The Epidemiologist R Handbook. Chapter 28: GIS Basics*. (2021). Retrieved 01 April 2022, from https://epirhandbook.com/en/gis-basics.html
- *Lovelace, R., Nowosad, J., & Muenchow, J. Geocomputation with R. Chapter 2: Geographic data in R*. (2019). Retrieved 01 April 2022, from https://geocompr.robinlovelace.net/spatial-class.html
- *Moraga, Paula. Geospatial Health Data: Modeling and Visualization with R-INLA and Shiny. Chapter 2: Spatial data and R packages for mapping*. (2019). Retrieved 01 April 2022, from https://www.paulamoraga.com/book-geospatial/sec-spatialdataandCRS.html
- *Baumer, Benjamin S., Kaplan, Daniel T., and Horton, Nicholas J. Modern Data Science with R. Chapter 17: Working with geospatial data*. (2021). Retrieved 05 June 2022, from https://mdsr-book.github.io/mdsr2e/ch-spatial.html