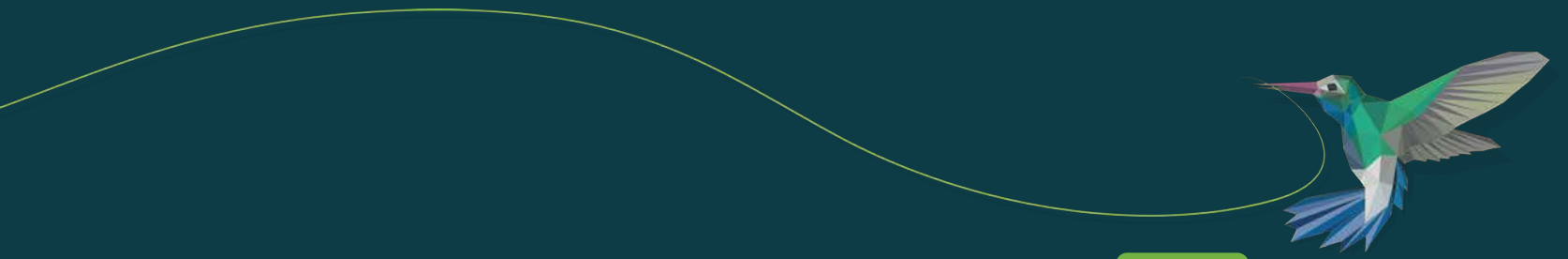
Raster Data and the {raster} package



ZevRoss
Know Your Data

The `raster` package is 10 years old!

But it has been around for so long for a reason

- It's powerful
- It's intuitive (at least I think so)
- Robert keeps it up to date

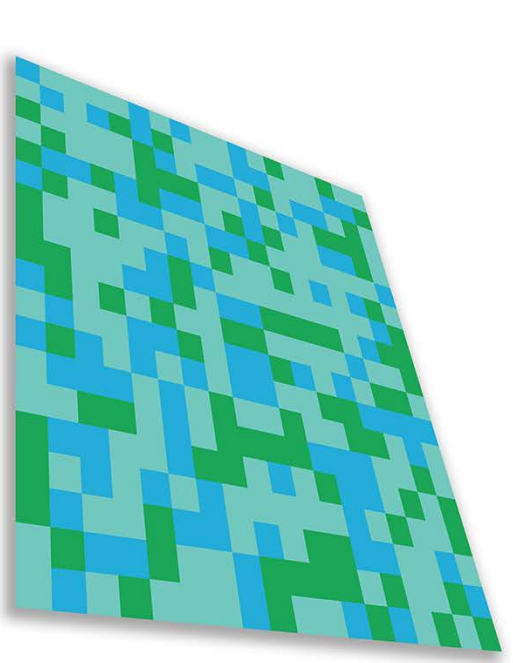
Robert J. Hijmans

Fully updated intro vignette

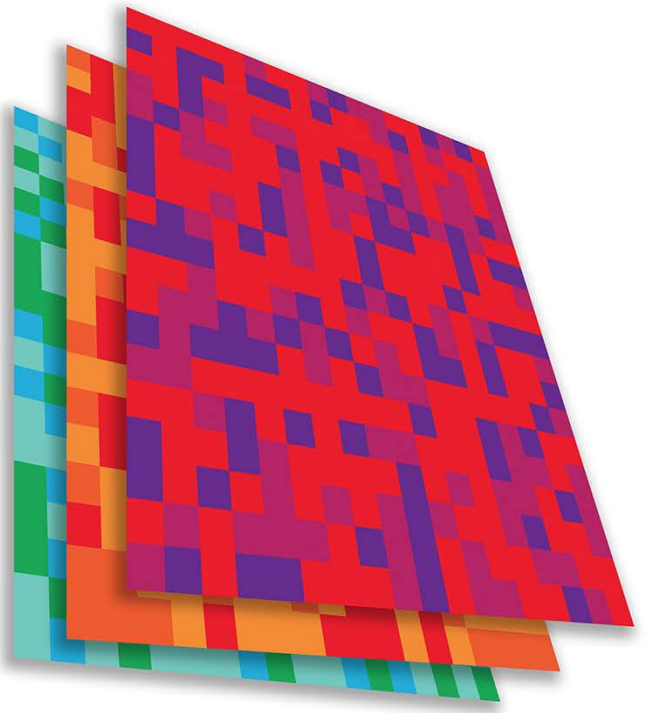
This is a useful reference.

As discussed earlier, "raster" refers to gridded data

And raster data can be single-band or multiple-band



Single Band Raster



Multi Band Raster

Read a single-band raster with `raster()`

```
elevation <- raster("data/elevation.tif", quiet = TRUE)
```

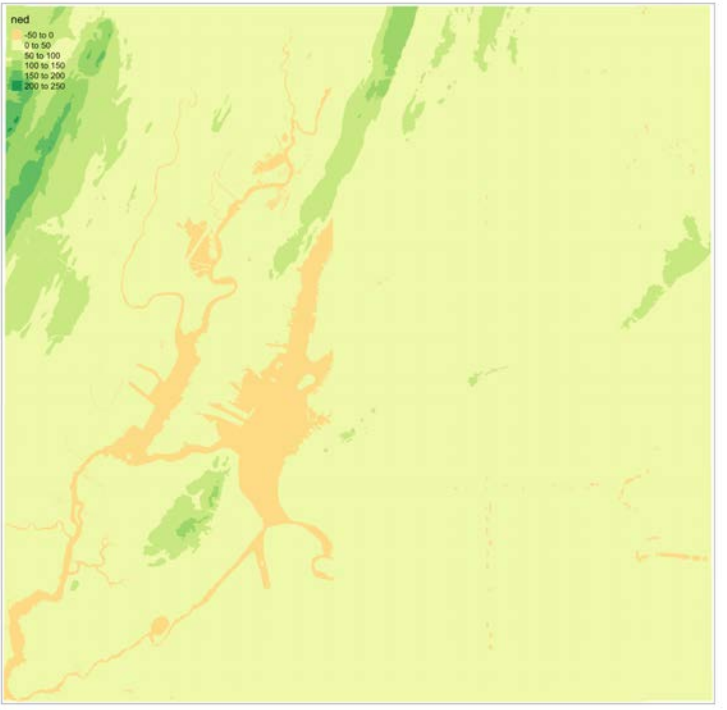
Single-band class is `RasterLayer`

```
class(elevation)
```

```
## [1] "RasterLayer"
## attr(,"package")
## [1] "raster"
```

Map the elevation data

```
tm_shape(elevation) +
  tm_raster()
```



Our `RasterLayer` metadata

```
elevation
```

```
## class      : RasterLayer
## dimensions : 1530, 2039, 3119670  (nrow, ncol, ncell)
## resolution : 77, 101  (x, y)
## extent     : 911860, 1068863, 119161.4, 273691.4  (xmin, xmax, ym
## crs        : +proj=lcc +lat_1=41.03333333333333 +lat_2=40.6666666
## source     : /Volumes/GoogleDrive/My Drive/projects/workshop-r-sp
## names      : ned
## values     : -14.05926, 209.7131  (min, max)
```

Read a multi-band raster with `brick()`

```
satellite_image <- brick("data/satellite.tif", quiet = TRUE)
```

Multi-band class is `RasterBrick`

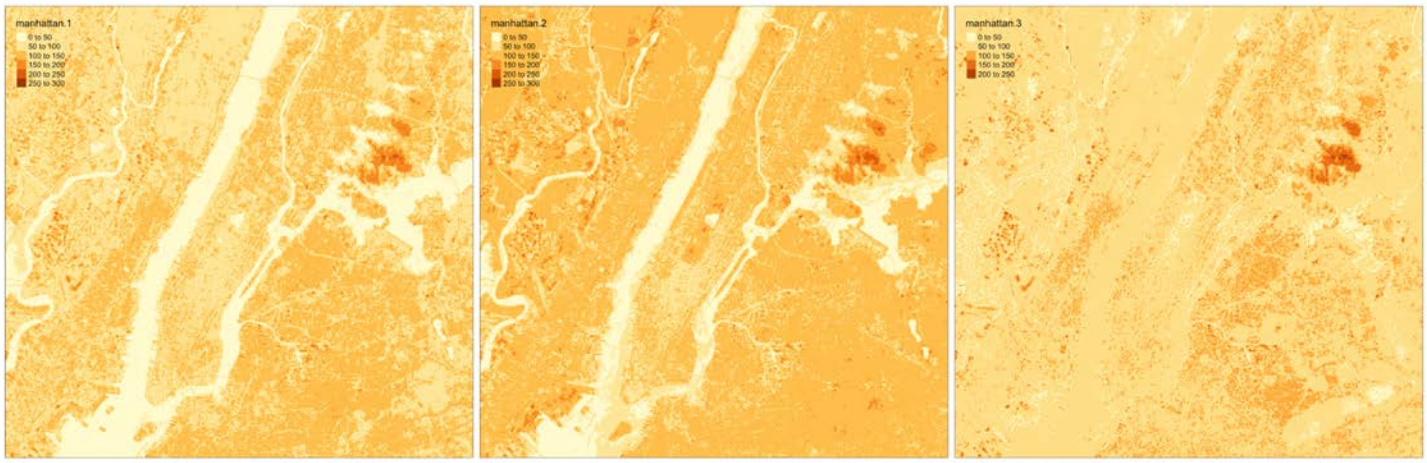
```
class(satellite_image)
```

```
## [1] "RasterBrick"
## attr(,"package")
## [1] "raster"
```

Map multi-band raster with `tm_raster()`

This is an image raster with a red, green and blue layer. What happens here?

```
tm_shape(satellite_image) + tm_raster()
```



Map our multi-band image with `tm_rgb()`

```
tm_shape(satellite_image) + tm_rgb()
```

The metadata in a `RasterBrick` object is very similar

```
satellite_image
```

```
## class      : RasterBrick
## dimensions : 773, 801, 619173, 3  (nrow, ncol, ncell, nlayers)
## resolution : 29.98979, 30.00062  (x, y)
## extent     : 575667.9, 599689.7, 4503277, 4526468  (xmin, xmax, y
## crs        : +proj=utm +zone=18 +datum=WGS84 +units=m +no_defs +e
## source     : /Users/zevross/git-repos/workshop-r-spatial-slides/d
## names      : manhattan.1, manhattan.2, manhattan.3
## min values :           0,           0,           0
## max values :         255,         255,         255
```

Get the names of your layers with `names()`

```
names(satellite_image)
```

```
## [1] "manhattan.1" "manhattan.2" "manhattan.3"
```

Two options for extracting a layer of your brick

```
satellite_image$manhattan.1
```

```
subset(satellite_image, "manhattan.1")
```

You can also use `raster()` and `brick()` to create a raster from scratch

Create a boring raster

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

Try to plot your boring raster

```
plot(r)
```

```
## Error in .plotraster2(x, col = col, maxpixels = maxpixels, add =
```

Why no plot?

Use the `getValues()` function to look at the values

```
getValues(r)
```

```
##   [1] NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA
##  [24] NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA
##  [47] NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA
##  [70] NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA
##  [93] NA NA NA NA NA NA NA NA
```

Can't plot a raster with no values

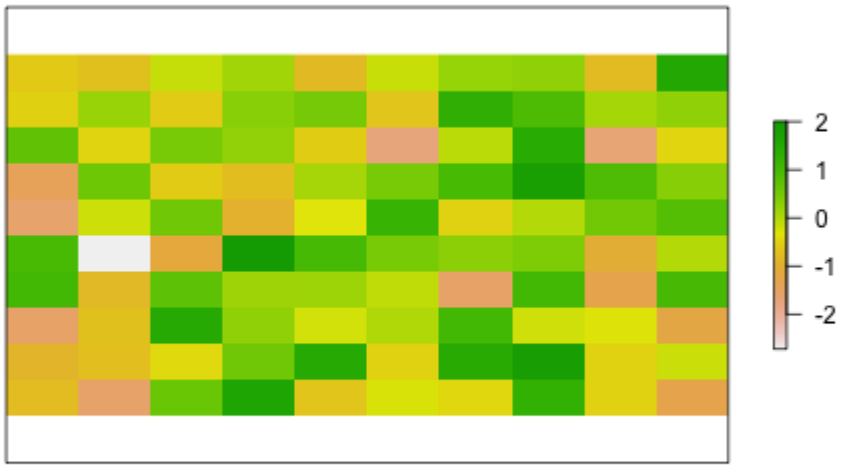
Use `values()` to add values

```
values(r) <- rnorm(100) # assign random normal data
```

```
# You can also include values when creating
r <- raster(nrow = 10, ncol = 10, vals = rnorm(100))
```

Now we can plot

```
plot(r, axes = FALSE)
```



Note that your cell values cannot be characters

```
my_letters <- sample(LETTERS, 100, replace = TRUE)
head(my_letters)
```

```
## [1] "Q" "B" "X" "X" "U" "B"
```

```
values(r) <- my_letters
```

```
## Error in setValues(x, value): values must be numeric, integer, lo
```

But they can be factors

```
values(r) <- factor(my_letters)
```

```
tm_shape(r) + tm_raster()
```

Technically the values stored are integers mapped to a table of levels

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

```
##  [1] 17  2 22 22 19  2 16 16 14  7
```

The levels of the categorical raster can be accessed with `levels()`

```
levels(r)[[1]][1:5,]
```

```
##   ID VALUE
## 1  1     A
## 2  2     B
## 3  3     C
## 4  4     D
## 5  5     E
```

A brick can be created by stacking `RasterLayers` with `brick()`

Perhaps the most boring brick ever created...

```
b <- brick(r, r, r)
b
```

```
## class      : RasterBrick
## dimensions : 10, 10, 100, 3  (nrow, ncol, ncell, nlayers)
## resolution : 36, 18  (x, y)
## extent     : -180, 180, -90, 90  (xmin, xmax, ymin, ymax)
## crs        : +proj=longlat +datum=WGS84 +ellps=WGS84 +towgs84=0,0
## source     : memory
## names      : layer.1, layer.2, layer.3
## min values :       1,       1,       1
## max values :      24,      24,      24
```

Where, on earth, are those rasters we just created?

By default, those hand-created rasters span the globe

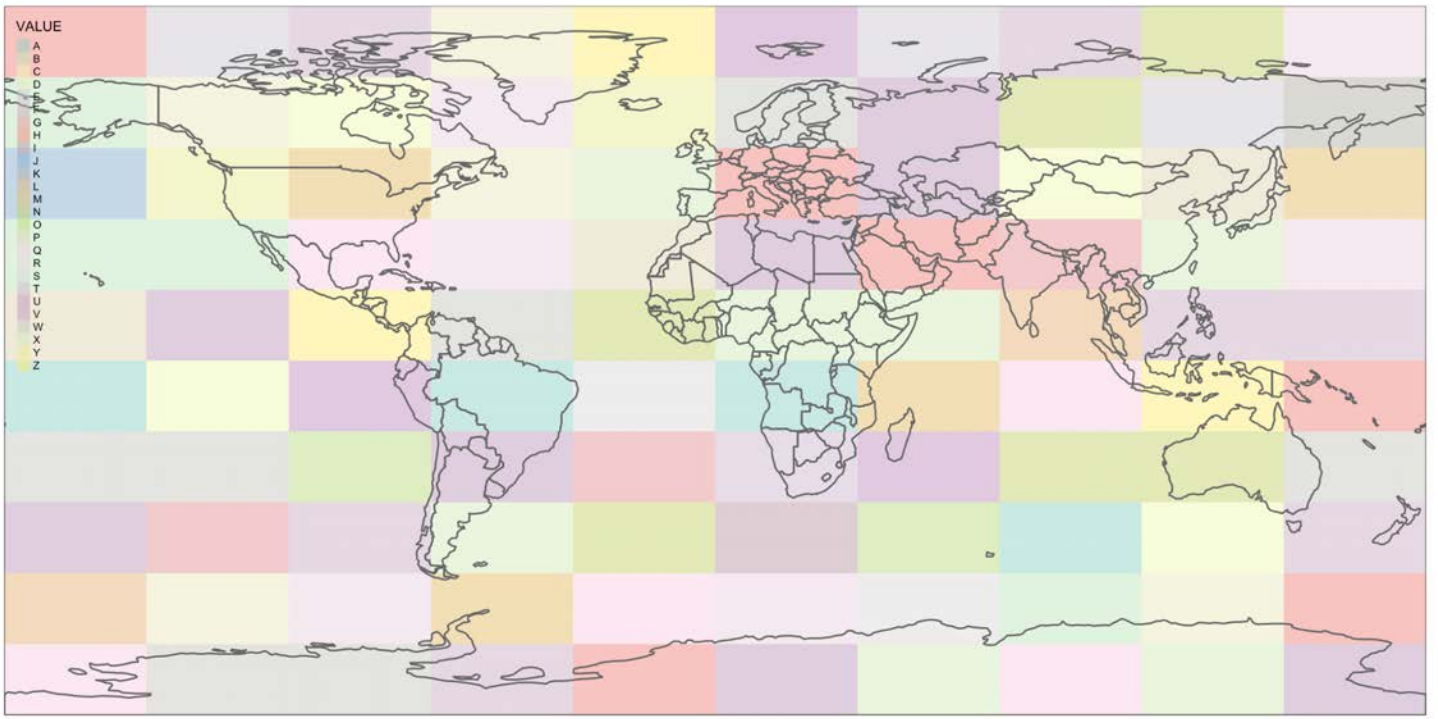
And have an unprojected CRS of WGS84

To prove this, read in the countries with {rnaturalearth} for context

```
countries <- rnaturalearth::ne_countries()
```

Map our random letters raster with countries on top

```
tm_shape(r) + tm_raster(alpha = 0.5) +
  tm_shape(countries) + tm_borders(lwd=2)
```



But if you want your raster in a specific place on earth

You can use another object to define the extent

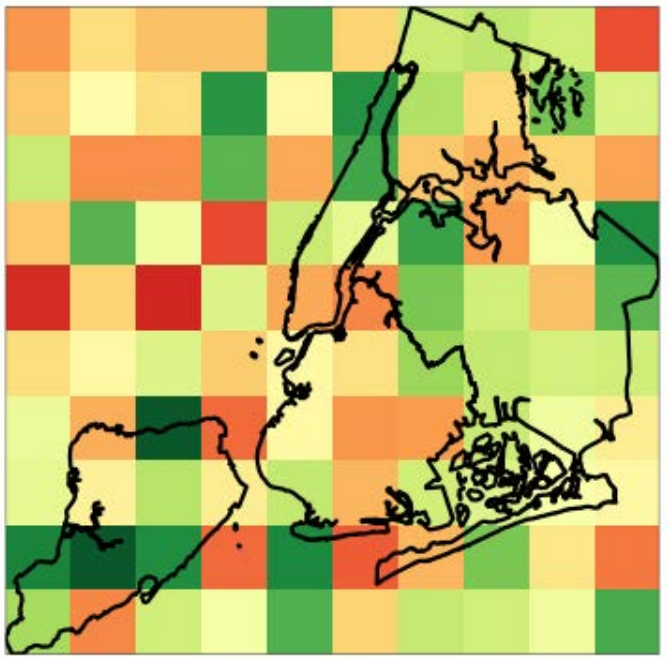
```
boroughs <- read_sf("boroughs.gpkg")
```

Supply the object to `raster()`

```
rand <- raster(boroughs, ncols = 10, nrows = 10,
               vals = rnorm(100))
```

Plot our random raster

```
tm_shape(rand) +
  tm_raster(n = 100, legend.show = FALSE) +
  tm_shape(boroughs) +
  tm_borders(lwd = 3, col = "black")
```



Extracting information about your rasters

The console printout shows the metadata

```
elevation
```

```
## class      : RasterLayer
## dimensions : 1530, 2039, 3119670  (nrow, ncol, ncell)
## resolution : 77, 101  (x, y)
## extent     : 911860, 1068863, 119161.4, 273691.4  (xmin, xmax, ym
## crs        : +proj=lcc +lat_1=41.03333333333333 +lat_2=40.6666666
## source     : /Volumes/GoogleDrive/My Drive/projects/workshop-r-sp
## names      : ned
## values     : -14.05926, 209.7131  (min, max)
```

You can access the "slots" (attributes) directly

```
elevation@crs
```

```
## CRS arguments:
##  +proj=lcc +lat_1=41.03333333333333 +lat_2=40.66666666666666
## +lat_0=40.16666666666666 +lon_0=-74 +x_0=300000.0000000001 +y_0=0
## +ellps=GRS80 +towgs84=0,0,0,0,0,0,0 +units=us-ft +no_defs
```

```
elevation@data@max
```

```
## [1] 209.7131
```

But there are utility functions to make it easier

```
crs(elevation)
```

```
## CRS arguments:
##  +proj=lcc +lat_1=41.03333333333333 +lat_2=40.66666666666666
## +lat_0=40.16666666666666 +lon_0=-74 +x_0=300000.0000000001 +y_0=0
## +ellps=GRS80 +towgs84=0,0,0,0,0,0,0 +units=us-ft +no_defs
```

```
maxValue(elevation)
```

```
## [1] 209.7131
```

Many more useful utility functions

- `extent()`
- `ncell()`
- `nlayers()`
- `filename()`
- `crs()`
- `minValue()`

Get cell value counts with `freq()`

```
r <- raster(nrow = 100, ncol = 100,
            vals = sample(1:10, 100*100, replace = TRUE))
```

```
freq(r) %>%
  head()
```

```
##      value count
## [1,]     1   992
## [2,]     2   969
## [3,]     3   956
## [4,]     4  1027
## [5,]     5  1053
## [6,]     6  1006
```

{raster} can work with large rasters

The elevation raster has a lot of grid cells

```
ncell(elevation)
```

```
## [1] 3119670
```

More than 3 million cells but in R it takes little memory

```
pryr::object_size(elevation)
```

```
## 11.6 kB
```

On disk, the file is not small

```
# Size on my computer
fs::file_info("elevation.tif")$size
```

```
## 10.2M
```

Raster values are not read by default

- Rasters can be very big
- To conserve memory raster values are imported only when required
- For large rasters, data is processed in chunks

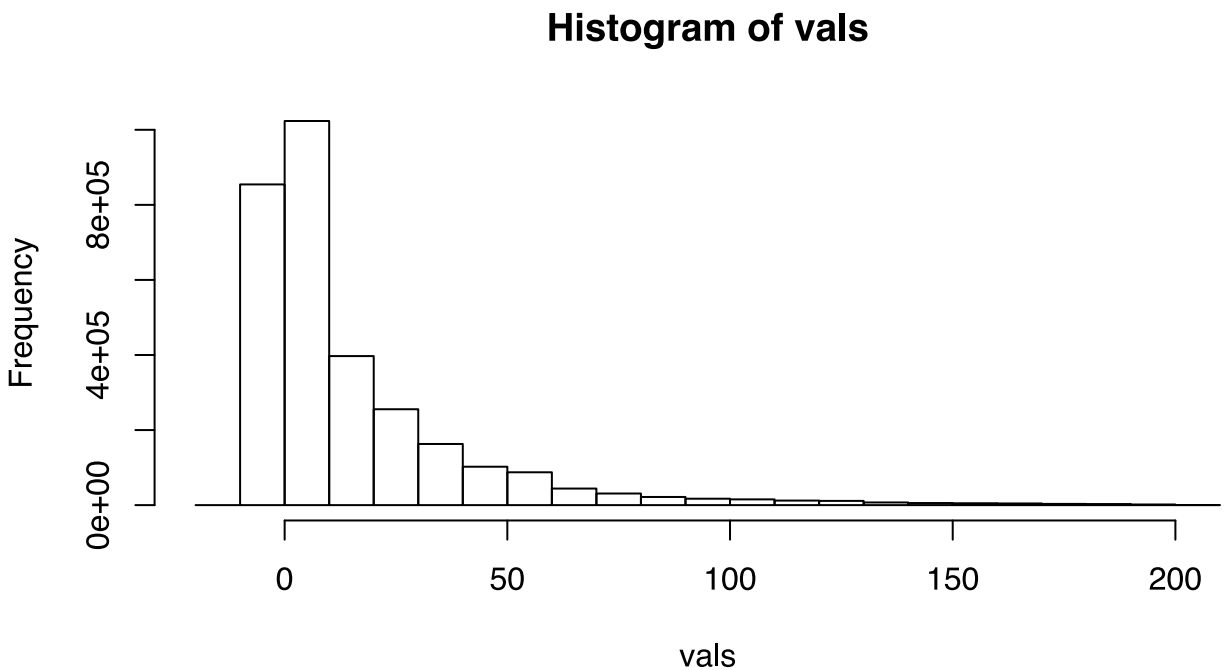
The `inMemory()` function tells you if the raster values have been read into R

```
inMemory(satellite_image)
```

```
## [1] FALSE
```

Read values with the `getValues()` function

```
vals <- getValues(elevation)
hist(vals)
```



Converting between vectors and rasters

Note that while there is some support for {sf} in {raster} it is not complete

You'll need to review the function documentation to determine what type of input is accepted

If a function only accepts a `Spatial*` object you can convert with `as()`

```
class(boroughs)
```

```
## [1] "sf"         "tbl_df"     "tbl"        "data.frame"
```

```
as(boroughs, "Spatial") %>% class()
```

```
## [1] "SpatialPolygonsDataFrame"
## attr(,"package")
## [1] "sp"
```

Use the `rasterize()` function to convert vectors to raster

For large rasters this can be computationally intensive and the {fasterize} package can help speed things up

You might do this for landscape analysis or raster math

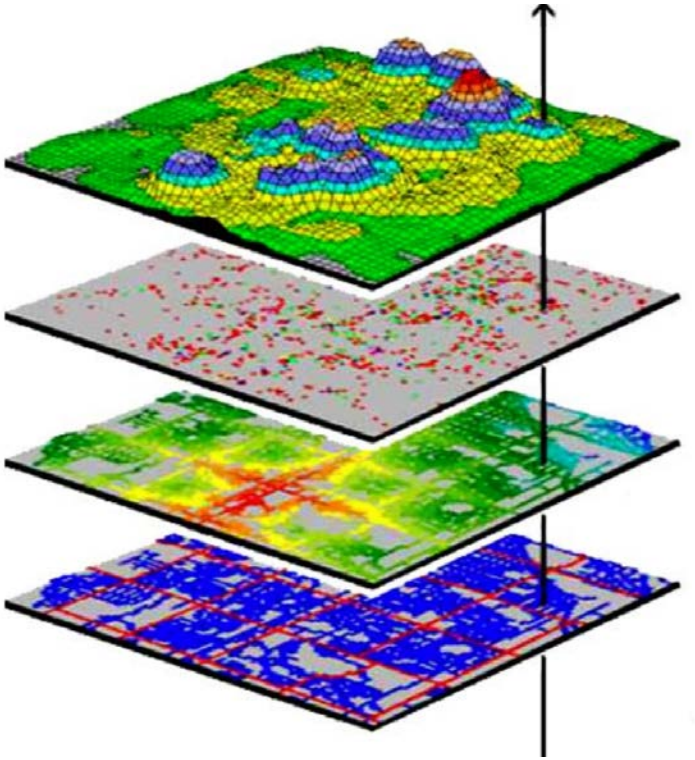


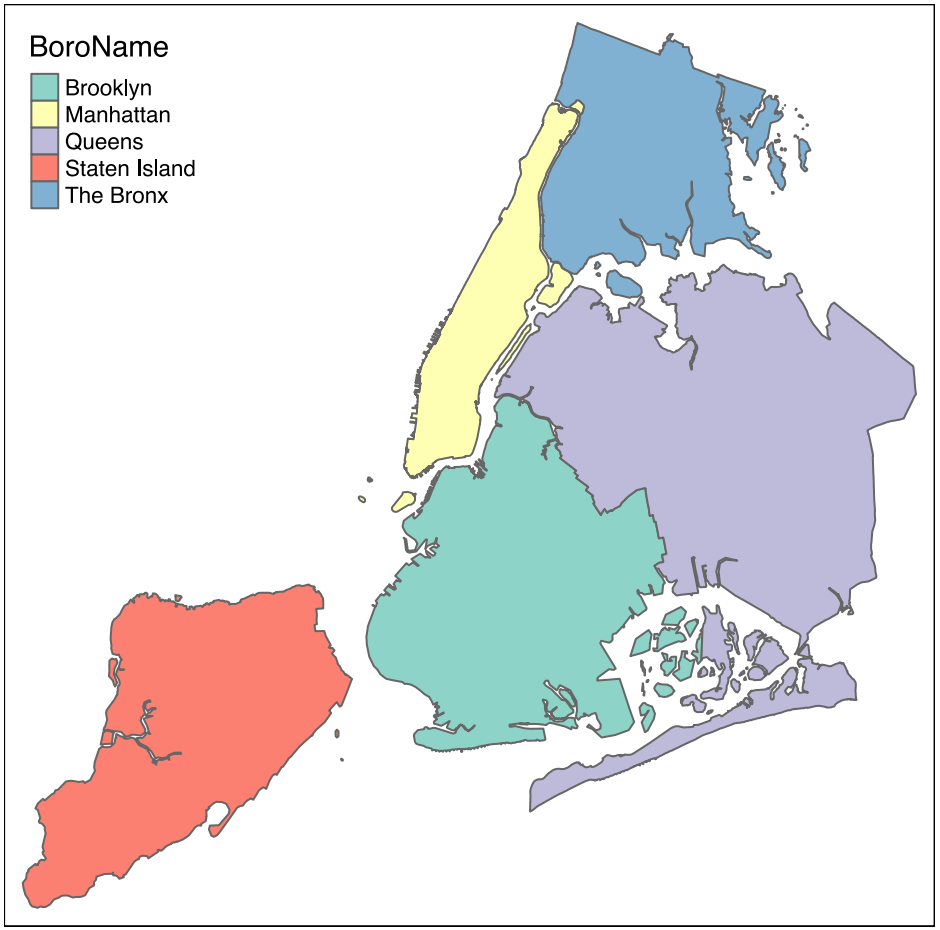
Image source

With `rasterize()` you assign the attributes from a vector layer to a raster

For this example we will create a raster layer of the boroughs

Our boroughs vector data

```
tm_shape(boroughs) + tm_polygons("BoroName")
```



Our boroughs attribute table

```
glimpse(boroughs)
```

```
## Observations: 5
## Variables: 7
## $ BoroCode   <int> 1, 2, 5, 3, 4
## $ BoroName   <chr> "Manhattan", "The Bronx", "Staten…
## $ Shape_Leng <dbl> 339736.6, 397460.6, 318700.5, 576…
## $ Shape_Area <dbl> 635147797, 1182399343, 1630762350…
## $ diso       <int> 1, 1, 1, 1, 1
## $ AreaSqMile <dbl> 22.78279, 42.41274, 58.49555, 71.…
## $ geom       <MULTIPOLYGON [US_survey_foot]> MULTIPO…
```

Step 1: Convert to an {sp} object

After reviewing the help for `rasterize()`

```
boroughs_sp <- as(boroughs, "Spatial")
```

Step 2: create the raster that values will be transferred to

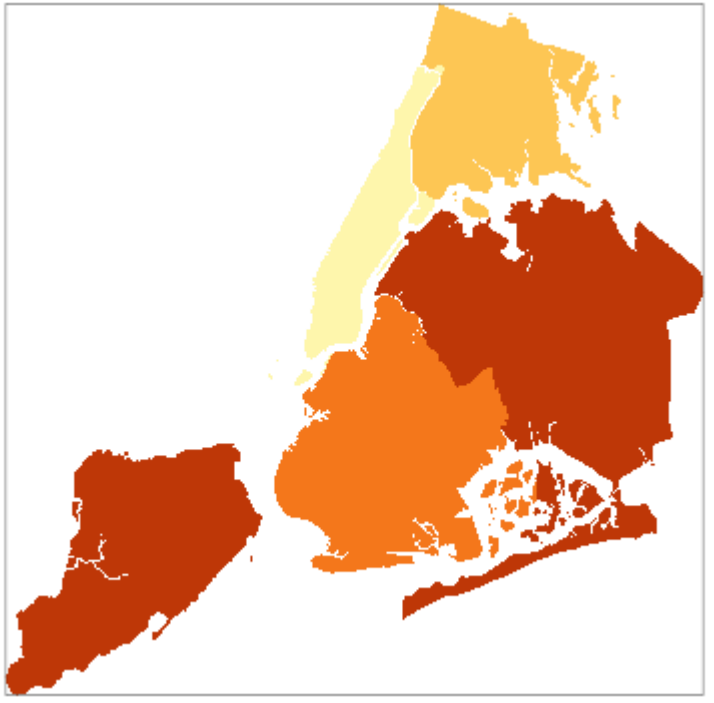
```
n <- 1000
r <- raster(boroughs_sp, ncols = n, nrows = n)
```

Run `rasterize()`

```
boro_raster <- rasterize(boroughs_sp, r, field = "BoroCode")
```

Our rasterized boroughs

```
tm_shape(boro_raster) + tm_raster() + tm_layout(legend.show
```



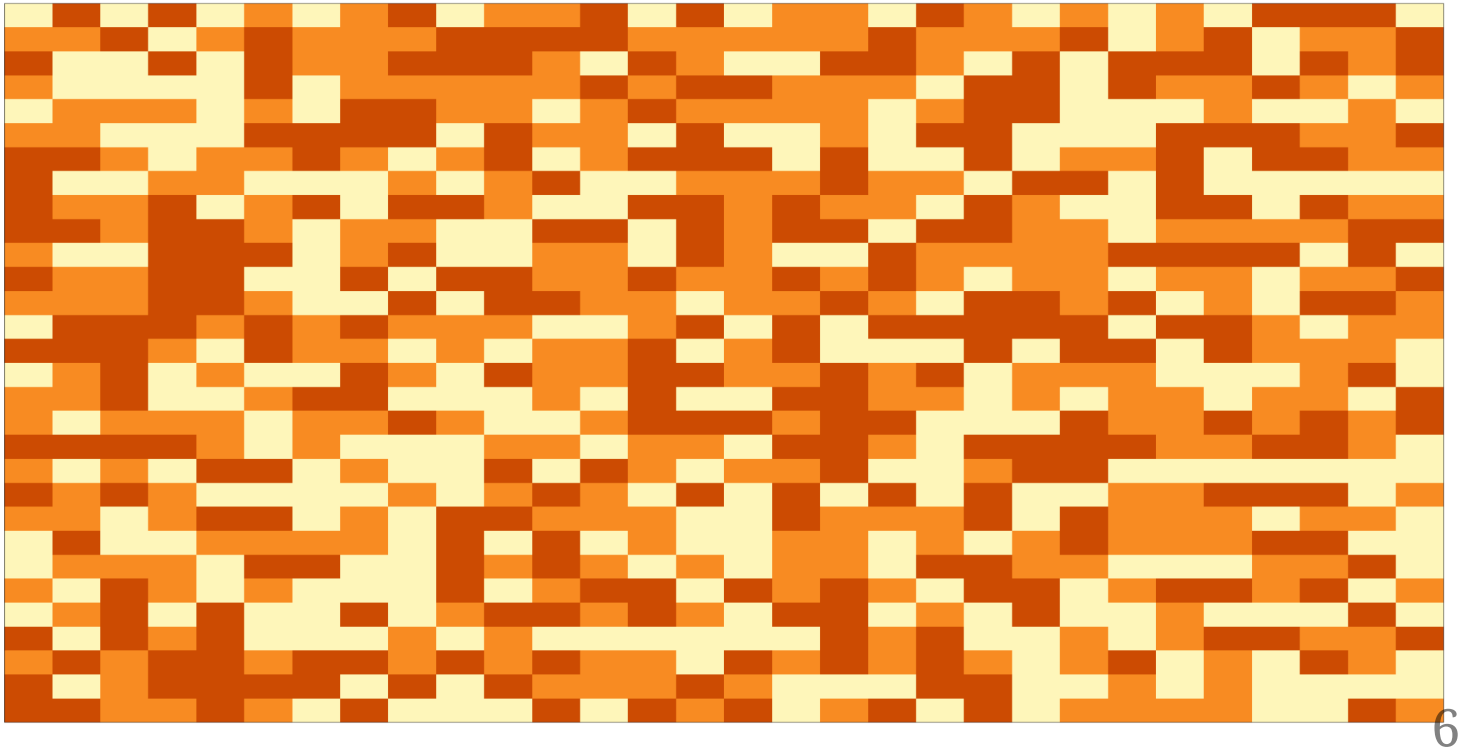
For converting from a raster to vectors you can use

- `rasterToPolygons()`
- `rasterToPoints()`

Create a random raster for this example

```
set.seed(100)
r <- raster(nrow = 30, ncol = 30,
            vals = sample(1:3, 900, replace = TRUE))
```

```
tm_shape(r) + tm_raster() + tm_layout(legend.show = FALSE)
```



Extract points from the raster

As a Spatial* object with `spatial = TRUE`

```
pts <- rasterToPoints(r, spatial = TRUE)
```

```
class(pts)
```

```
## [1] "SpatialPointsDataFrame"
## attr(,"package")
## [1] "sp"
```

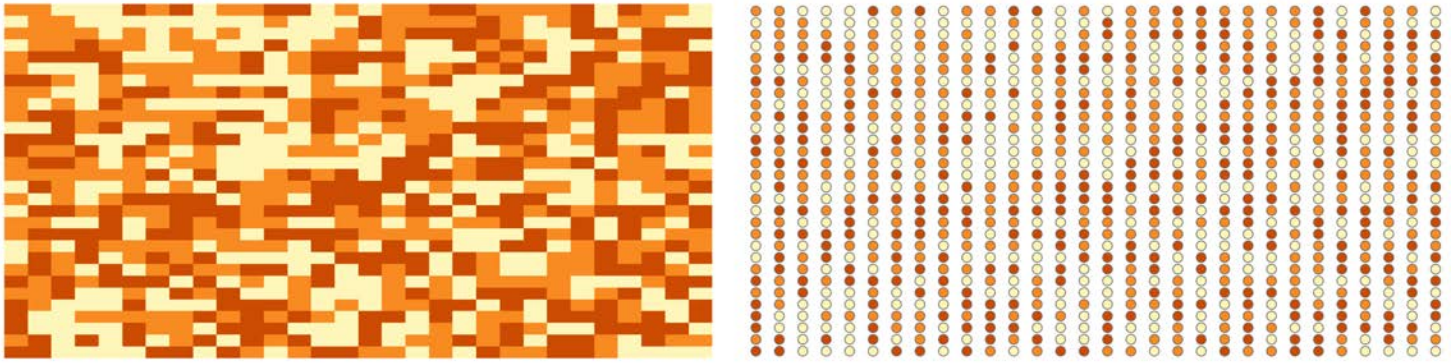
Convert to an {sf} object

```
pts <- as(pts, "sf")
```

```
# This also works
pts <- st_as_sf(pts)
```

Plot the points

```
my_layout <-   tm_layout(frame = FALSE, legend.show = FALSE)
m1 <- tm_shape(r) + tm_raster() + my_layout
m2 <- tm_shape(pts) + tm_dots("layer", size = 0.5, shape = 2
tmap_arrange(m1, m2, nrow = 1)
```

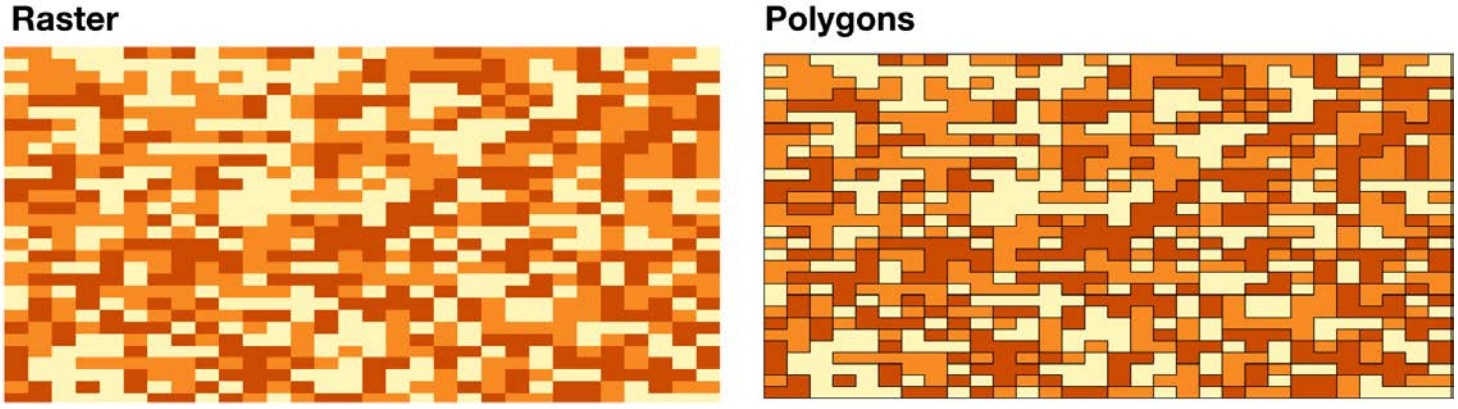


Extract the polygons

```
polys <- rasterToPolygons(r, dissolve = TRUE) %>%
  st_as_sf(sf)
```

Plot the polys

```
m3 <- tm_shape(polys) +
  tm_polygons("layer", border.col = "black") + my_layout
tmap_arrange(m1, m3, nrow = 1)
```



open_exercise(6)