

Reproducible Reporting with R (R^3) for marine ecosystem indicators

Contents

Overview	5
Github	5
Google Drive	6
Resources	6
Software Setup	6
0.1 Install software	6
0.2 Launch RStudio	6
0.3 Fork and Clone the Github Repository	7
0.4 Install R Packages	7
0.5 Create Rmarkdown file	8
 1 Collaborate: git, github	 11
1.1 Setup Github & Git	11
1.2 Github Workflows	12
1.3 Create Repository <code>nps-demo</code>	12
1.4 Create <code>index.html</code>	14
1.5 Create RStudio Project with Git Repository	14
1.6 Create <code>index.Rmd</code> in Rmarkdown	15
1.7 Exercise: Intertidal Sites Dataset	15
 2 Manipulate: tidyr, dplyr	 17
2.1 install our first package: <code>dplyr</code>	18
2.2 Use <code>dplyr::filter()</code> to subset data row-wise.	18
2.3 Meet the new pipe operator	19
2.4 Use <code>dplyr::select()</code> to subset the data on variables or columns.	20
2.5 Revel in the convenience	21
2.6 Use <code>mutate()</code> to add new variables	22
2.7 <code>group_by</code> and <code>summarize</code>	22
2.8 Remember our for loop?	23
2.9 Summary	24
2.10 Further materials as reference...	25
 3 Visualize: ggplot2, plotly, tmap	 27
3.1 Plot	27

3.2	Map	37
3.3	References	39
4	Analyze Spatial: sf	41
4.1	Overview	41
4.2	Prerequisites	41
4.3	States: read and plot	42
4.4	Challenge: analytical steps?	45
4.5	Regions: calculate % water	45
4.6	Regions: plot	47
4.7	Regions: ggplot	47
4.8	Regions: recalculate area	48
4.9	Challenge: project & recalculate area	49
4.10	Key Points	51
5	Interactive Map: leaflet	53
5.1	Overview	53
5.2	Things You'll Need to Complete this Tutorial	53
5.3	States: ggplot2	54
5.4	States: plotly	55
5.5	States: mapview	55
5.6	States: leaflet	57
5.7	Challenge: leaflet for regions	60
5.8	Raster: leaflet	62
5.9	Key Points	62
A	Appendix Shiny Google Auth	63

Overview

These materials are for a 1-day workshop on Reproducible Reporting with R for the Working Group on the Northwest Atlantic Regional Sea (WGNARS) at Dartmouth SMAST on March 16, 2020.

- **Location:** School for Marine Science & Technology (SMAST), UMass Dartmouth 706 S Rodney French Blvd, New Bedford, MA 02744
- **Date:** Monday, March 16, 2020

Marine ecosystem indicators are ideally developed in an efficient, transparent, time sensitive manner so as to consistently and effectively support decision-making by managers and inform on ecosystem status for the general public. In this workshop we will demonstrate the use of the R scripting language for automating the ingestion and wrangling of data, calculation of indicators, visualization of maps or time series and online communication with interactive or static reports. We will also use Github to version and collaboratively develop code, communicate technically and host free websites. Finally, development of interactive user applications using Shiny and interactive infographics using a custom library will be briefly reviewed. Please check back here for the latest online materials.

This is the landing site for our workshop materials. Google Drive (folders, docs, slides, sheets, etc.) allows us to be agile with adapting content on the fly. The rest of the content in this site is generated using the techniques taught: R + markdown = Rmarkdown, git, Github, etc.

Github

Here is the Github repository of the source files for this website:

- github.com/ecoquants/r3-workshop

Google Drive

- **workshop/**
 - **agenda**
 - **notes**
 - **presentations/**
 - **data/**

Resources

Online books: - R for Data Science - Spatial Data Analysis and Modeling with R

Software Setup

0.1 Install software

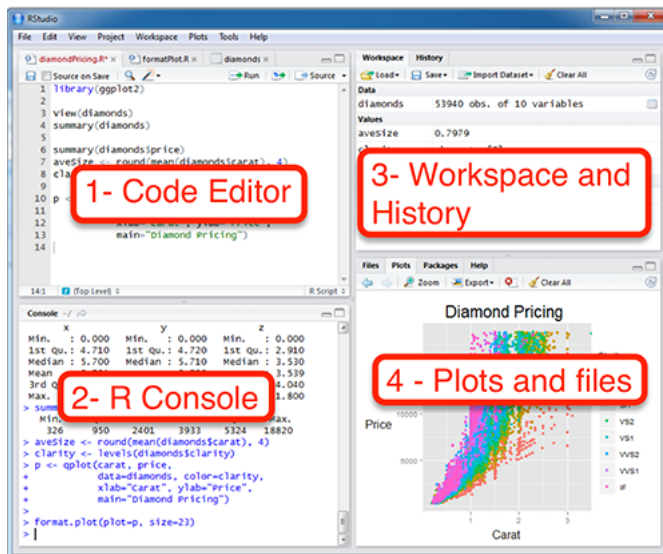
This workshop will require the following software installed on your machine:

- R scientific programming language
- RStudio integrated development environment
- Git version control

Please download the appropriate stable release for your operating system.

0.2 Launch RStudio

RStudio is an integrated development environment (IDE) for editing text in the code editor, running commands in the R console, viewing defined objects in the workspace and past commands in the history, and viewing plots, files and help. Here's a layout of the panes in RStudio, each of which can have several tabs for alternate functionality:



Check out the Help > Cheatsheets > RStudio IDE Cheat Sheet.

0.3 Fork and Clone the Github Repository

If you'd like to play with these materials directly and keep track of differences, please visit:

<https://github.com/bbest/meds-demo>

While signed into Github, fork the repo into your own writable user space so you can clone it in RStudio.

Then you can follow along in RStudio by evaluating the chunks of R code, while referencing this website:

<http://benbestphd.com/meds-demo>

0.4 Install R Packages

Here's a bit of code to ensure you have all the necessary packages installed. Please copy and paste this code into your R Console.

```
## R version 4.0.2 (2020-06-22)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Catalina 10.15.7
##
## Matrix products: default
```

```
## BLAS:    /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRblas.dylib
## LAPACK:  /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] stats      graphics  grDevices  utils      datasets  methods   base
##
## other attached packages:
## [1] keras_2.3.0.0      tensorflow_2.2.0   textdata_0.4.1     tidytext_0.2.5
## [5] rtweet_0.7.0       plotly_4.9.2.1     jsonlite_1.7.1     units_0.6-7
## [9] lubridate_1.7.9.2  scales_1.1.1       glue_1.4.2         here_0.1
## [13] librarian_1.7.0    sf_0.9-6           leaflet_2.0.3      knitr_1.30
## [17] forcats_0.5.0      stringr_1.4.0      dplyr_1.0.2        purrr_0.3.4
## [21] readr_1.4.0        tidyr_1.1.2        tibble_3.0.4       ggplot2_3.3.2
## [25] tidyverse_1.3.0
##
## loaded via a namespace (and not attached):
## [1] fs_1.5.0           httr_1.4.2         rprojroot_2.0.2    SnowballC_0.7.0
## [5] tools_4.0.2        backports_1.2.0    R6_2.5.0           KernSmooth_2.23-17
## [9] DBI_1.1.0          lazyeval_0.2.2     colorspace_2.0-0   withr_2.3.0
## [13] tidyselect_1.1.0   compiler_4.0.2     cli_2.2.0          rvest_0.3.6
## [17] xml2_1.3.2         bookdown_0.21.2    classInt_0.4-3     tfruns_1.4
## [21] digest_0.6.27      rmarkdown_2.5      base64enc_0.1-3    pkgconfig_2.0.3
## [25] htmltools_0.5.0    dbplyr_1.4.4       htmlwidgets_1.5.2  rlang_0.4.9
## [29] readxl_1.3.1       rstudioapi_0.13    generics_0.1.0     crosstalk_1.1.0.1
## [33] tokenizers_0.2.1   magrittr_2.0.1     Matrix_1.2-18      Rcpp_1.0.5
## [37] munsell_0.5.0      fansi_0.4.1        reticulate_1.16    lifecycle_0.2.0
## [41] whisker_0.4        stringi_1.5.3      yaml_2.2.1         grid_4.0.2
## [45] blob_1.2.1         crayon_1.3.4       lattice_0.20-41    haven_2.3.1
## [49] hms_0.5.3          zeallot_0.1.0      pillar_1.4.7       reprex_0.3.0
## [53] evaluate_0.14      data.table_1.13.2  modelr_0.1.8       vctrs_0.3.5
## [57] cellranger_1.1.0   gtable_0.3.0       assertthat_0.2.1   xfun_0.19
## [61] broom_0.7.2        e1071_1.7-4        janeaustenr_0.1.5  class_7.3-17
## [65] viridisLite_0.3.0 ellipsis_0.3.1
```

0.5 Create Rmarkdown file

Rmarkdown is a dynamic document format that allows you to knit chunks of R code with formatted text (aka markdown). We recommend that you use this format for keeping a reproducible research document as you work through the lessons To get started, File > New File > Rmarkdown... and go with default HTML document and give any title you like (default “Untitled” or “test” or

“First Rmd” is fine).

Check out the [Help > Markdown Quick Reference](#) and [Help > Cheatsheets > R Markdown Cheat Sheet](#).

Here’s a 1 minute video on the awesomeness of Rmarkdown:

Chapter 1

Collaborate: git, github

This section is paired with:

- Data Wrangling in the R Tidyverse - Google Slides

The two main tools you'll learn about to start are:

- **Git** is a version control system that lets you track changes to files over time. These files can be any kind of file (eg doc, pdf, xls), but free text differences are most easily visible (eg txt, csv, md). You can rollback changes made by you, or others. This facilitates a playground for collaboration, without fear of experimentation (you can always rollback changes).
- **Github** is a website for storing your git versioned files remotely. It has many nice features to be able visualize differences between images, rendering & diffing map data files, render text data files, and track changes in text.

Steps:

1. Create Github login
2. Create project website with Github Pages
3. Edit README.md in Markdown
4. Create HTML website content with R Markdown

1.1 Setup Github & Git

1. Create **Github** account at <http://github.com>, if you don't already have one. For username, I recommend all lower-case letters, short as you can. If you use an email ending in **.edu**, you can request free private repositories via GitHub Education discount.

2. Configure **git** with global commands. Open up the Bash version of Git and type the following:

```
# display your version of git
git --version

# replace USER with your Github user account
git config --global user.name USER

# replace USER@SOMEWHERE.EDU with the email you used to register with Github
git config --global user.email USER@SOMEWHERE.EDU

# list your config to confirm user.* variables set
git config --list
```

1.2 Github Workflows

The two most common workflow models for working Github repositories is based on your permissions:

1. **writable**: Push & Pull (simplest)
2. **read only**: Fork & Pull Request (extra steps)

We will only go over the first writable mode. For more on the second mode, see [Forking Projects · GitHub Guides](#).

1.2.1 Push & Pull

repo location	initialize	edit	update
github.com/OWNER/REPO	create		
~/github/REPO	clone	commit , push	pull

Note that OWNER could be either an individual USER or group ORGANIZATION, which has member USERS.

1.3 Create Repository `nps-demo`

Now you will create a Github repository for a project.

1. Create a repository called `my-project`.

Please be sure to tick the box to **Initialize this repository with a README**. Otherwise defaults are fine.

2. Create a branch called **gh-pages**.

Per pages.github.com, since this will be a project site only web files in the **gh-pages** branch will show up at <http://USER.github.io/REPO>. For a user (or organization) site, the REPO must be named **USER.github.io** (or **ORG.github.io**) and then the default **master** branch will contain the web files for the website <http://USER.github.io> (or <http://ORG.github.io>). See also User, Organization, and Project Pages - Github Help.

3. Set the default branch to **gh-pages**, NOT the default **master**.

4. Delete the branch **master**, which will not be used.

1.3.1 Edit README.md in Markdown

Commit your first change by editing the **README.md** which is in **markdown**, simple syntax for conversion to HTML. Now update the contents of the **README.md** with the following, having a link and a numbered list:

```
# nps-demo
```

```
Wrangling data with R.
```

```
## Introduction
```

```
This repository demonstrates software and _formats_:
```

- ```
1. Git
1. Github
1. _Markdown_
1. _Rmarkdown_
```

```
Conclusion
```

```

```

Now click on the **Preview changes** to see the markdown rendered as HTML:

Notice the syntax for:

- **numbered list** gets automatically sequenced: 1., 1.
- **headers** get rendered at multiple levels: #, ##
- **link**: `[] (http://...)`
- **image**: `![] (http://...)`
- *italics*: `_word_`

- **bold:** **\*\*word\*\***

See Mastering Markdown · GitHub Guides and add some more personalized content to the README of your own, like a bulleted list or blockquote.

## 1.4 Create index.html

By default `index.html` is served up. Go ahead and create a new file named `index.html` with the following basic HTML:

```
<!DOCTYPE html>
<html>
<body>

<h1>My First Heading</h1>

<p>My first paragraph.</p>

</body>
</html>
```

You'll be prompted to clone this repository into a folder on your local machine.

See GitHub Desktop User Guides for more. You could also do this from the Bash Shell for Git with the command `git clone https://github.com/USER/REPO.git`, replacing `USER` with your Github username and `REPO` with `my_project`. Or you can use the Github Desktop App menu `File -> Clone Repository...`

## 1.5 Create RStudio Project with Git Repository

Next, you will clone the repository onto your local machine using RStudio. I recommend creating it in a folder `github` under your user or Documents folder.

Open RStudio and under the menu `File -> New Project... -> Version Control -> git` and enter the URL with the `.git` extension (also available from the repository's Clone button):

If it all works correctly then you should see the files downloaded and showing up in the Files pane of RStudio. If RStudio is configured correctly to work with Git, then you should also see a Git pane.

## 1.6 Create index.Rmd in Rmarkdown

Back in RStudio, let's create a new Rmarkdown file, which allows us to weave markdown text with chunks of R code to be evaluated and output content like tables and plots.

File -> New File -> Rmarkdown... -> Document of output format HTML, OK.

You can give it a Title of "My Project". After you click OK, most importantly File -> Save as `index` (which will get named with the filename extension `index.Rmd`).

Some initial text is already provided for you. Let's go ahead and "Knit HTML".

Notice how the markdown is rendered similar to as before + **R code chunks** are surrounded by 3 backticks and `{r LABEL}`. These are evaluated and return the output text in the case of `summary(cars)` and the output plot in the case of `plot(pressure)`.

Notice how the code `plot(pressure)` is not shown in the HTML output because of the R code chunk option `echo=FALSE`.

Before we continue exploring Rmarkdown, visit the Git pane, check all modified (M) or untracked (?) files, click Commit, enter a message like "added index" and click the "Commit" button. Then Push (up green arrow) to push the locally committed changes on your lapto up to the Github repository online. This will update <https://github.com/USER/nps-demo>, and now you can also see your project website with a default `index.html` viewable at <http://USER.github.io/nps-demo>

For more on Rmarkdown:

- [rmarkdown cheatsheet.pdf](#)
- [rmarkdown.rstudio.com](http://rmarkdown.rstudio.com)
- [knitr in a knutshell - Karl Broman](#)

A more advanced topic worth mentioning is dealing merge conflicts

## 1.7 Exercise: Intertidal Sites Dataset

Gil Rilov shared the following dataset for us to play with:

- [Israel sites fall 2015-16.xlsx](#)

Please download and open this dataset. Your task is to investigate this dataset and prepare it for submission to OBIS.

### 1.7.1 Task: Provide Excel cell ranges for how you would divide data into tables?

For reading and wrangling data in R, please see cheat sheets and resources mentioned in:

- Data Wrangling in the R Tidyverse - Google Slides



## Chapter 2

# Manipulate: `tidyr`, `dplyr`

Data scientists, according to interviews and expert estimates, spend from 50 percent to 80 percent of their time mired in the mundane labor of collecting and preparing data, before it can be explored for useful information. - NYTimes (2014)

Today we're going to learn about a package by Hadley Wickham called `dplyr` and how it will help you with simple data exploration, and how you can use it in combination with the `%>%` operator for more complex wrangling (including a lot of the things you would use for loops for).

And we're going to do this in Rmarkdown in the `my-project` repository we created this morning.

Here are the steps:

1. Open RStudio
2. Make sure you're in your `my-project` repo (and if not, get there)
3. New > Rmarkdown... (defaults are fine)
4. Save as `gapminder-dplyr.rmd`
5. Our workflow together will be to write some description of our analysis in Markdown for humans to read, and we will write all of our R code in the 'chunks'. Get ready for the awesomeness, here we go...

Today's materials are again borrowing from some excellent sources, including

- Dr. Jenny Bryan's lectures from STAT545 at UBC: Introduction to `dplyr`
- Software Carpentry's R for reproducible scientific analysis materials: Dataframe manipulation with `dplyr`

## 2.1 install our first package: dplyr

Packages are bundles of functions, along with help pages and other goodies that make them easier for others to use, (ie. vignettes).

So far we've been using packages included in 'base R'; they are 'out-of-the-box' functions. You can also install packages from online. The most traditional is CRAN, the Comprehensive R Archive Network. This is where you went to download R originally, and will go again to look for updates.

You don't need to go to CRAN's website to install packages, we can do it from within R with the command `install.packages("package-name-in-quotes")`.

```
from CRAN:
#install.packages("dplyr") ## do this once only to install the package on your computer

library(dplyr) ## do this every time you restart R and need it
select <- dplyr::select # overwrite raster::select
```

What's the difference between `install.packages()` and `library()`? Here's my analogy:

- `install.packages()` is setting up electricity for your house. Just need to do this once (let's ignore monthly bills).
- `library()` is turning on the lights. You only turn them on when you need them, otherwise it wouldn't be efficient. And when you quit R, and come back, you'll have to turn them on again with `library()`, but you already have your electricity set up.

## 2.2 Use `dplyr::filter()` to subset data row-wise.

First let's read in the gapminder data.

```
install.packages('gapminder') # instead of reading in the csv
library(gapminder) # this is the package name
str(gapminder) # and it's also the data.frame name, just like yesterday

tibble [1,704 x 6] (S3: tbl_df/tbl/data.frame)
$ country : Factor w/ 142 levels "Afghanistan",...: 1 1 1 1 1 1 1 1 1 1 ...
$ continent: Factor w/ 5 levels "Africa","Americas",...: 3 3 3 3 3 3 3 3 3 3 ...
$ year : int [1:1704] 1952 1957 1962 1967 1972 1977 1982 1987 1992 1997 ...
$ lifeExp : num [1:1704] 28.8 30.3 32 34 36.1 ...
$ pop : int [1:1704] 8425333 9240934 10267083 11537966 13079460 14880372 1288...
$ gdpPercap: num [1:1704] 779 821 853 836 740 ...
```

`filter()` takes logical expressions and returns the rows for which all are TRUE. Visually, we are doing this (thanks RStudio for your cheatsheet):

## Subset Observations (Rows)



```
filter(gapminder, lifeExp < 29)
filter(gapminder, country == "Rwanda")
filter(gapminder, country %in% c("Rwanda", "Afghanistan"))
```

Compare with some base R code to accomplish the same things

```
gapminder[gapminder$lifeExp < 29,] ## repeat `gapminder`, [i, j] indexing is distracting
subset(gapminder, country == "Rwanda") ## almost same as filter ... but wait ...
```

## 2.3 Meet the new pipe operator

Before we go any further, we should exploit the new pipe operator that `dplyr` imports from the `magrittr` package by Stefan Bache. **This is going to change your data analytical life.** You no longer need to enact multi-operation commands by nesting them inside each other. This new syntax leads to code that is much easier to write and to read.

Here's what it looks like: `%>%`. The RStudio keyboard shortcut: Ctrl + Shift + M (Windows), Cmd + Shift + M (Mac).

Let's demo then I'll explain:

```
gapminder %>% head
```

This is equivalent to `head(gapminder)`. This pipe operator takes the thing on the left-hand-side and **pipes** it into the function call on the right-hand-side – literally, drops it in as the first argument.

Never fear, you can still specify other arguments to this function! To see the first 3 rows of Gapminder, we could say `head(gapminder, 3)` or this:

```
gapminder %>% head(3)
```

I've advised you to think “gets” whenever you see the assignment operator, `<-`. Similarly, you should think “then” whenever you see the pipe operator, `%>%`.

You are probably not impressed yet, but the magic will soon happen.

## 2.4 Use `dplyr::select()` to subset the data on variables or columns.

Back to `dplyr` ...

Use `select()` to subset the data on variables or columns. Visually, we are doing this (thanks RStudio for your cheatsheet):

### Subset Variables (Columns)



Here's a conventional call:

```
select(gapminder, year, lifeExp)
```

But using what we just learned, with a pipe, we can do this:

```
gapminder %>% select(year, lifeExp)
```

Let's write it again but using multiple lines so it's nicer to read. And let's add a second pipe operator to pipe through `head`:

```
gapminder %>%
 select(year, lifeExp) %>%
 head(4)
```

```
A tibble: 4 x 2
year lifeExp
<int> <dbl>
1 1952 28.8
2 1957 30.3
3 1962 32.0
4 1967 34.0
```

Think: “Take `gapminder`, then select the variables `year` and `lifeExp`, then show the first 4 rows.”

## 2.5 Revel in the convenience

Let's do a little analysis where we calculate the mean gdp for Cambodia.

Here's the gapminder data for Cambodia, but only certain variables:

```
gapminder %>%
 filter(country == "Cambodia") %>%
 # select(country, year, pop, gdpPercap) ## entering 4 of the 6 columns is tedious
 select(-continent, -lifeExp) # you can use - to deselect columns
```

and what a typical base R call would look like:

```
gapminder[gapminder$country == "Cambodia", c("country", "year", "pop", "gdpPercap")]
```

```
A tibble: 12 x 4
country year pop gdpPercap
<fct> <int> <int> <dbl>
1 Cambodia 1952 4693836 368.
2 Cambodia 1957 5322536 434.
3 Cambodia 1962 6083619 497.
4 Cambodia 1967 6960067 523.
5 Cambodia 1972 7450606 422.
6 Cambodia 1977 6978607 525.
7 Cambodia 1982 7272485 624.
8 Cambodia 1987 8371791 684.
9 Cambodia 1992 10150094 682.
10 Cambodia 1997 11782962 734.
11 Cambodia 2002 12926707 896.
12 Cambodia 2007 14131858 1714.
```

or, possibly?, a nicer look using base R's `subset()` function:

```
subset(gapminder, country == "Cambodia", select = c(country, year, pop, gdpPercap))
```

```
A tibble: 12 x 4
country year pop gdpPercap
<fct> <int> <int> <dbl>
1 Cambodia 1952 4693836 368.
2 Cambodia 1957 5322536 434.
3 Cambodia 1962 6083619 497.
4 Cambodia 1967 6960067 523.
5 Cambodia 1972 7450606 422.
6 Cambodia 1977 6978607 525.
7 Cambodia 1982 7272485 624.
8 Cambodia 1987 8371791 684.
9 Cambodia 1992 10150094 682.
10 Cambodia 1997 11782962 734.
```

```
11 Cambodia 2002 12926707 896.
12 Cambodia 2007 14131858 1714.
```

## 2.6 Use `mutate()` to add new variables

Imagine we wanted to recover each country's GDP. After all, the Gapminder data has a variable for population and GDP per capita. Let's add a new column and multiply them together.

Visually, we are doing this (thanks RStudio for your cheatsheet):

### Make New Variables



```
gapminder %>%
 mutate(gdp = pop * gdpPerCap)
```

Exercise: how would you add that to the previous `filter` and `select` commands we did with Cambodia:

```
gapminder %>%
 filter(country == "Cambodia") %>%
 select(-continent, -lifeExp)
```

Answer:

```
gapminder %>%
 filter(country == "Cambodia") %>%
 select(-continent, -lifeExp) %>%
 mutate(gdp = pop * gdpPerCap)
```

## 2.7 `group_by` and `summarize`

Great! And now we want to calculate the mean gdp across all years (Let's pretend that's a good idea statistically)

Visually, we are doing this (thanks RStudio for your cheatsheet):

## Summarise Data



```
gapminder %>%
 filter(country == "Cambodia") %>%
 select(-continent, -lifeExp) %>%
 mutate(gdp = pop * gdpPercap) %>%
 group_by(country) %>%
 summarize(mean_gdp = mean(gdp)) %>%
 ungroup() # if you use group_by, also use ungroup() to save heartache later
```

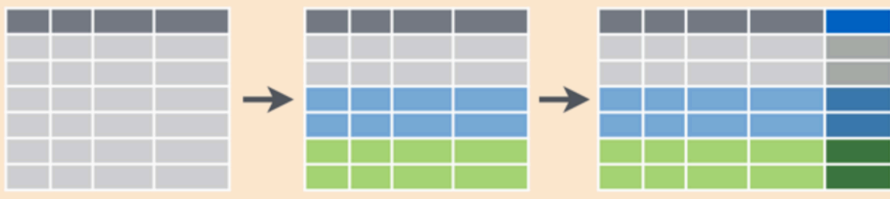
## 2.8 Remember our for loop?

And how would you then do this for every country, not just Cambodia? Well, yesterday we would have been thinking about putting this whole analysis inside a for loop, replacing “Cambodia” with a new name each time we iterated through the loop. But today, we have it already, just need to *delete* one line from our analysis—we don’t need to filter out Cambodia anymore!!

Visually, we are doing this (thanks RStudio for your cheatsheet):

## Group Data

Compute new variables by group.



```
gapminder %>%
 select(-continent, -lifeExp) %>%
 mutate(gdp = pop * gdpPercap) %>%
 group_by(country) %>%
 summarize(mean_gdp = mean(gdp)) %>%
 ungroup() # if you use group_by, also use ungroup() to save heartache later
```

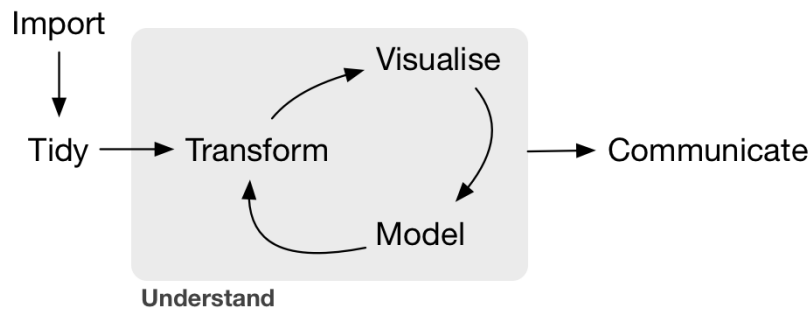
So we have done a pretty incredible amount of work in a few lines. Our whole analysis is this. Imagine the possibilities from here.

```
library(dplyr)

gapminder %>%
 read.csv('data/gapminder-FiveYearData.csv') %>%
 select(-continent, -lifeExp) %>%
 mutate(gdp = pop * gdpPerCap) %>%
 group_by(country) %>%
 summarize(mean_gdp = mean(gdp)) %>%
 ungroup() # if you use group_by, also use ungroup() to save heartache later
```

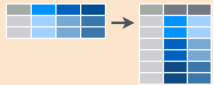



## 2.9 Summary

This has been the ‘Tranform’ or Wrangling part of this cycle.



Importing and tidying is also a HUGE part of this process, and we don’t have time to get into it today. But look at the cheatsheet, and watch the webinar. cheatsheet and webinar. Watch this 1 hour webinar and follow along in RStudio and your science will be forever changed. Again!

Reshaping Data - Change the layout of a data set

 <p><b>tidyr::gather(cases, "year", "n", 2:4)</b> Gather columns into rows.</p>	 <p><b>tidyr::spread(pollution, size, amount)</b> Spread rows into columns.</p>	<p><b>dplyr::data_frame(a = 1:3, b = 4:6)</b> Combine vectors into data frame (optimized).</p> <p><b>dplyr::arrange(mtcars, mpg)</b> Order rows by values of a column (low to high).</p> <p><b>dplyr::arrange(mtcars, desc(mpg))</b> Order rows by values of a column (high to low).</p> <p><b>dplyr::rename(tb, y = year)</b> Rename the columns of a data frame.</p>
 <p><b>tidyr::separate(storms, date, c("y", "m", "d"))</b> Separate one column into several.</p>	 <p><b>tidyr::unite(data, col, ..., sep)</b> Unite several columns into one.</p>	



## 2.10 Further materials as reference...

### 2.10.1 Rationale

When performing data analysis in R, code can become quite messy, making it hard to revisit and determine the sequence of operations. Commenting helps. Good variable names help. Still, at least two common issues make code difficult to understand: **multiple variables** and **nested functions**. Let's examine these issues by approaching an analysis presenting both problems, and finally see how `dplyr` offers an elegant alternative.

For example, let's ask of the `surveys.csv` dataset: *How many observations of a certain thing you're interested in appear each year?*

### 2.10.2 Pseudocode

You can write the logic out as **pseudocode** which can become later comments for the actual code:

```
read in csv
view data
limit columns to species and year
limit rows to just species "NL"
get count per year
write out csv
```

### 2.10.3 Summary

The `tidyr` and `dplyr` packages were created by Hadley Wickham of `ggplot2` fame. The “gg” in `ggplot2` stands for the “grammar of graphics”. Hadley similarly considers the functionality of the two packages `dplyr` and `tidyr` to provide the “grammar of data manipulation”.

Next, we'll explore the data wrangling lessons that Remi contributed to Software Carpentry.

### 2.10.4 dplyr

`dplyr` - Software Carpentry

### 2.10.5 tidyr

`tidyr` - Software Carpentry

### 2.10.6 Other links

- Tidying up Data - Env Info - Rmd
- Data wrangling with dplyr and tidyr - Tyler Clavelle & Dan Ovando - Rmd

## Chapter 3

# Visualize: `ggplot2`, `plotly`, `tmap`

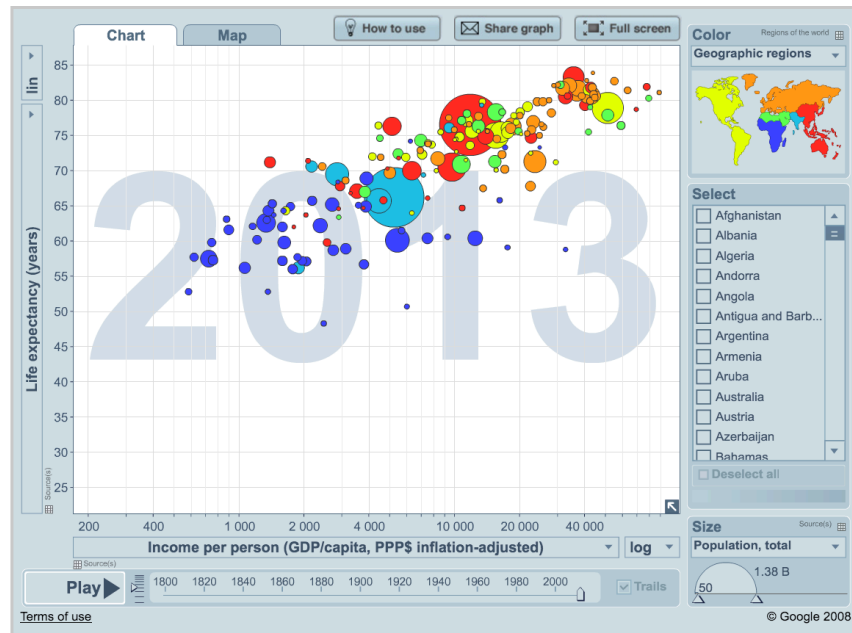
### 3.1 Plot

Inspiring people:

- **Hadley Wickham:** grammar of graphics
- **Hans Rosling:** Gapminder



Gapminder World - Wealth & Health of Nations



### 3.1.1 Static: ggplot

- Creating publication quality graphics - Software Carpentry

#### 3.1.1.1 Scatterplot

```
library(dplyr)
library(ggplot2)
library(gapminder)

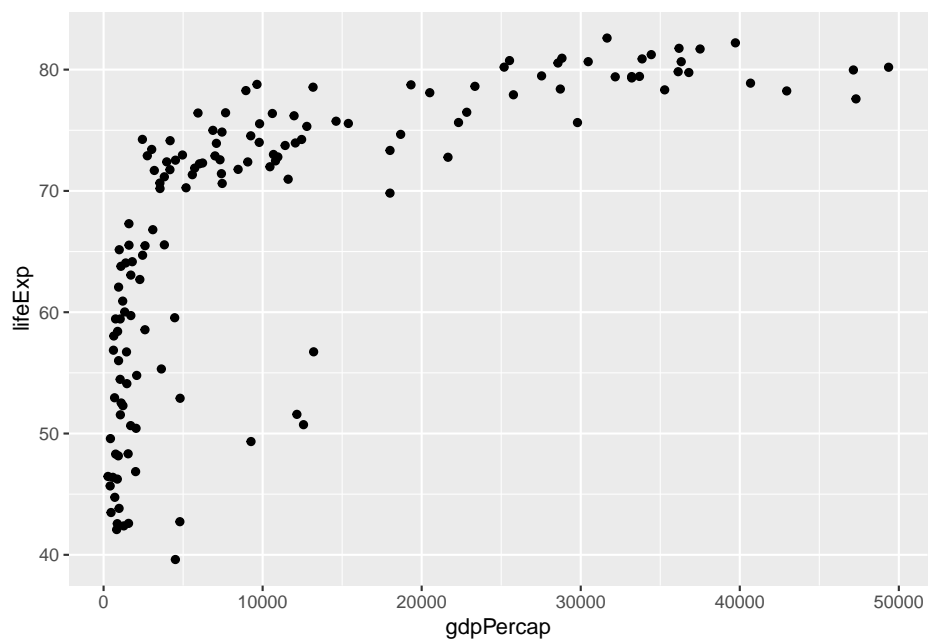
preview data
gapminder

get range of available data
summary(gapminder)

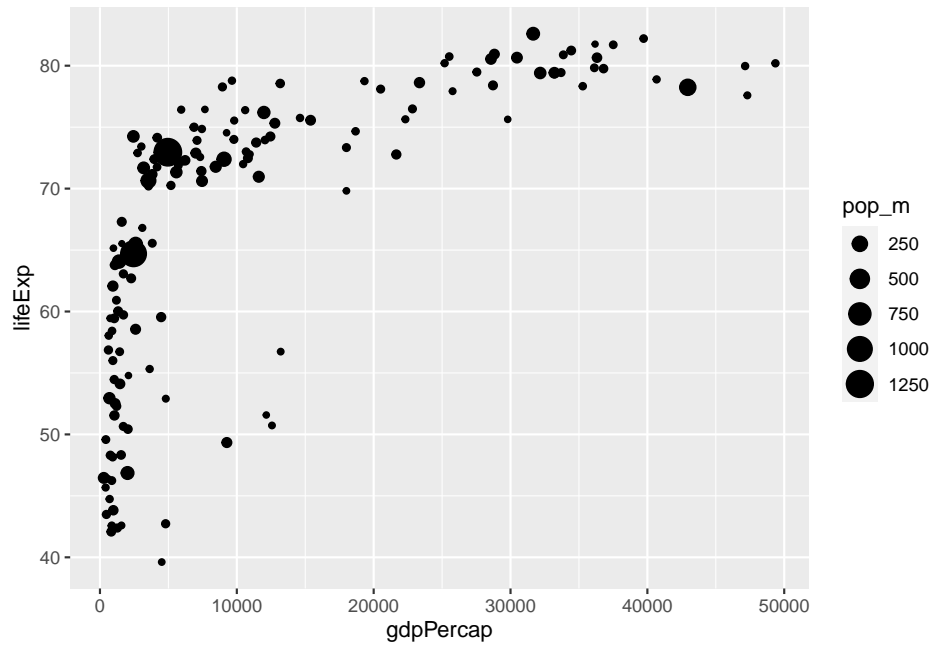
setup dataframe
g = gapminder %>%
 filter(year==2007) %>% # most recent year
 mutate(pop_m = pop/1e6) # population, millions

plot scatterplot of most recent year
s = ggplot(g, aes(x=gdpPercap, y=lifeExp)) +
```

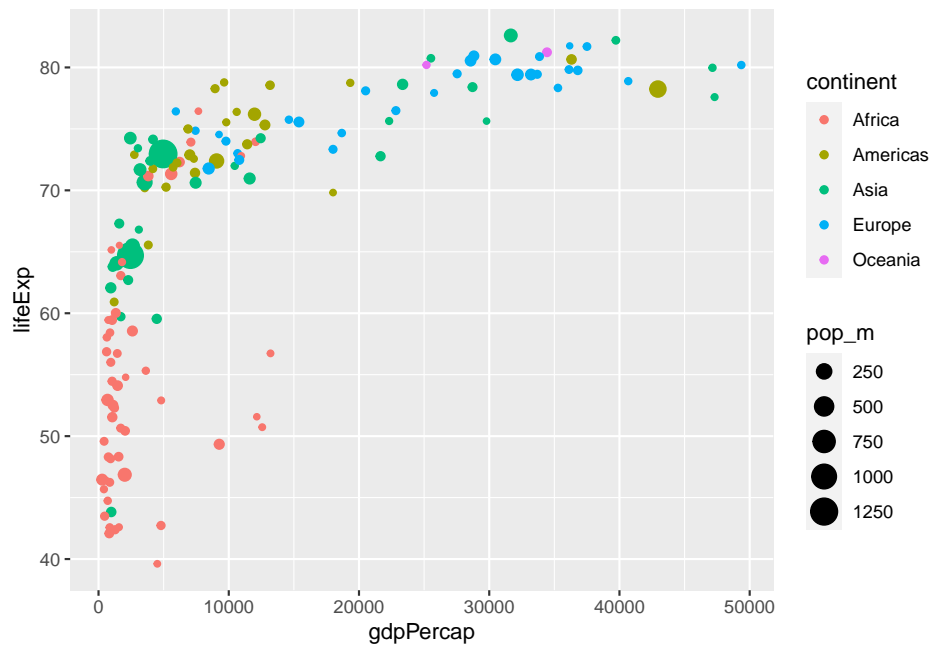
```
geom_point()
s
```



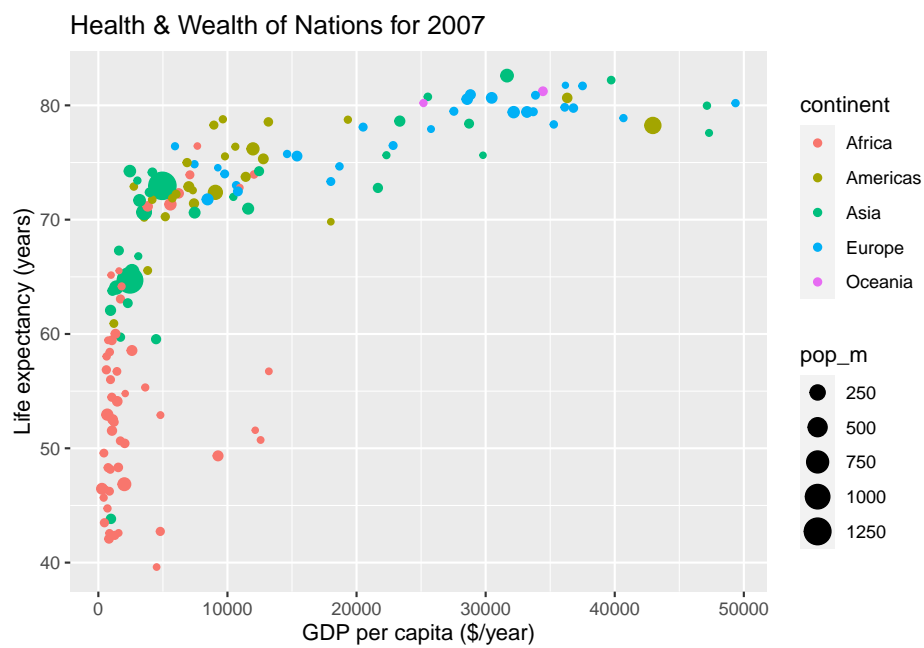
```
add aesthetic of size by population
s = s +
 aes(size=pop_m)
s
```



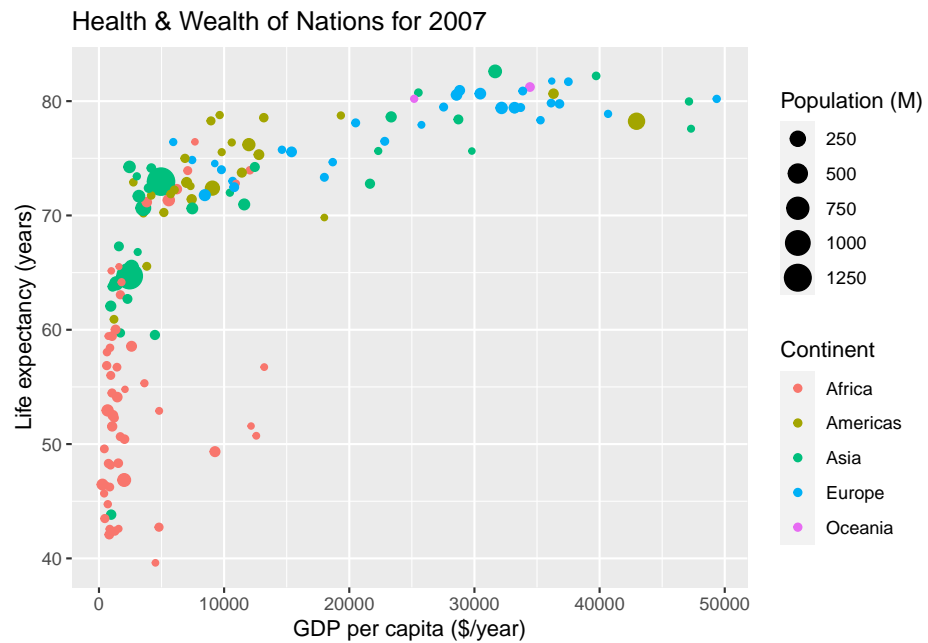
```
add aesthetic of color by continent
s = s +
 aes(color=continent)
s
```



```
add title, update axes labels
s = s +
 ggtitle('Health & Wealth of Nations for 2007') +
 xlab('GDP per capita ($/year)') +
 ylab('Life expectancy (years)')
s
```



```
label legend
s = s +
 scale_colour_discrete(name='Continent') +
 scale_size_continuous(name='Population (M)')
s
```



## Your Turn

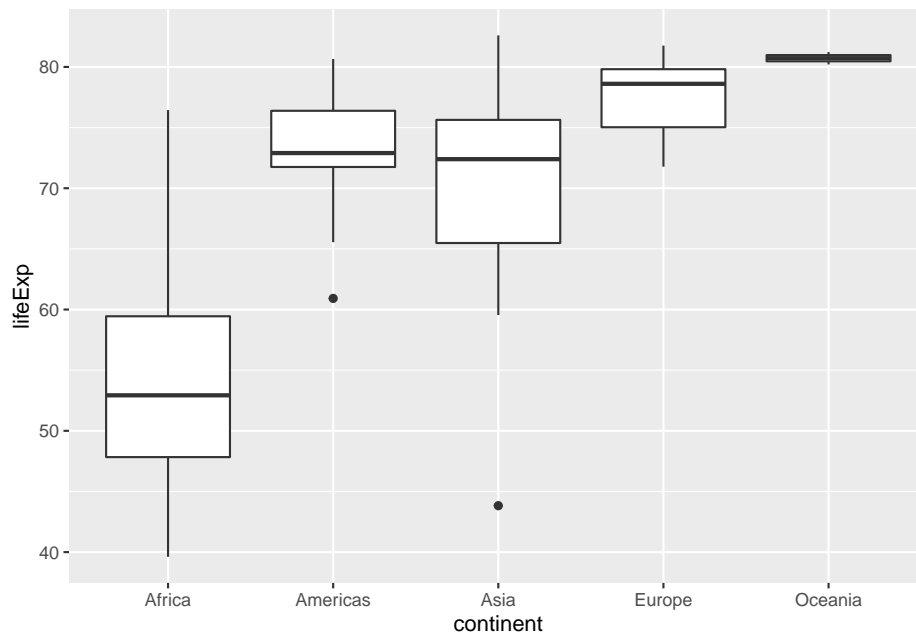
Now with country emissions datasets...

- CO2 Emissions from Fossil Fuels since 1751, By Nation - Dataset - Frictionless Open Data
- `datasets/gdp`

### 3.1.1.2 Boxplot

```
boxplot by continent
b = ggplot(g, aes(x=continent, y=lifeExp)) +
 geom_boxplot()
b
```

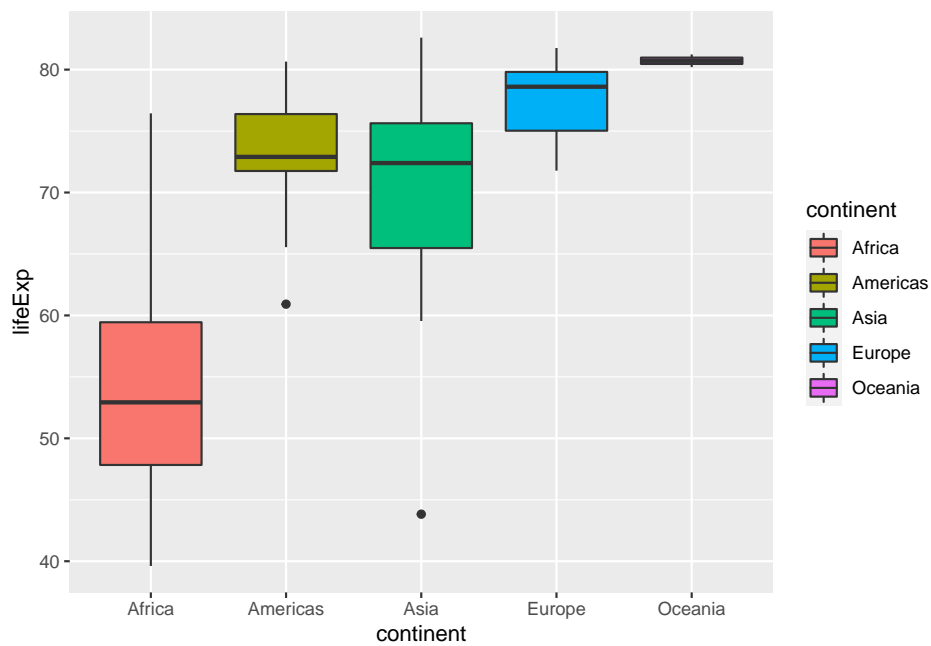




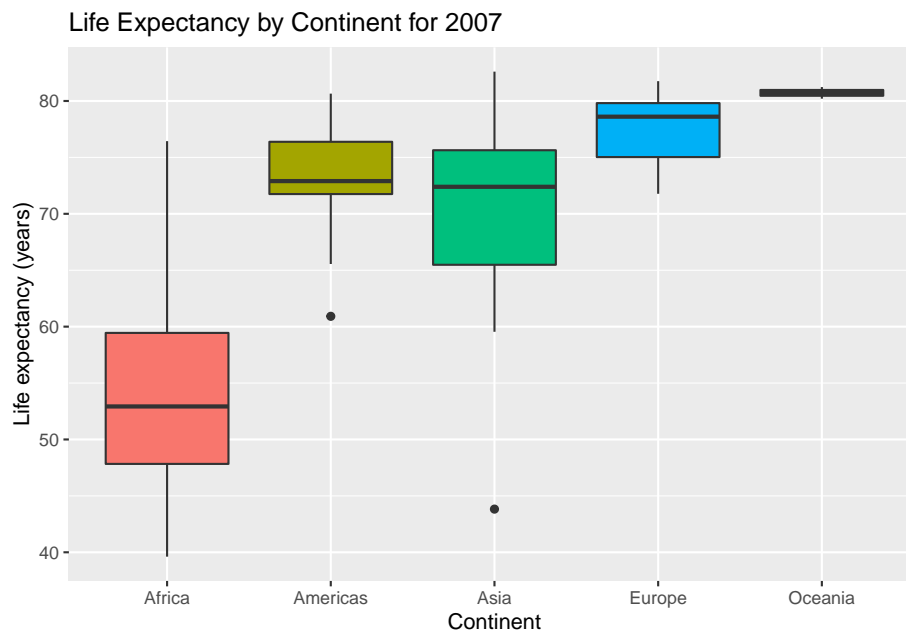
```
match color to continents, like scatterplot
```

```
b = b +
 aes(fill=continent)
```

```
b
```



```
drop legend, add title, update axes labels
b = b +
 theme(legend.position='none') +
 ggtitle('Life Expectancy by Continent for 2007') +
 xlab('Continent') +
 ylab('Life expectancy (years)')
b
```



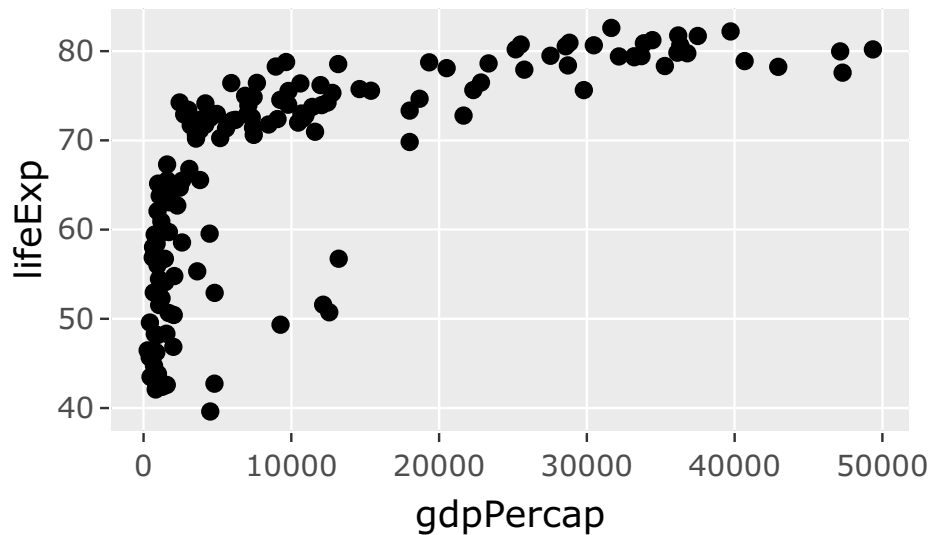
**Your Turn:** Make a similar plot but for `gdpPercap`. Be sure to update the plot's aesthetic, axis label and title accordingly.

### 3.1.2 Interactive: plotly

ggplot2 | plotly

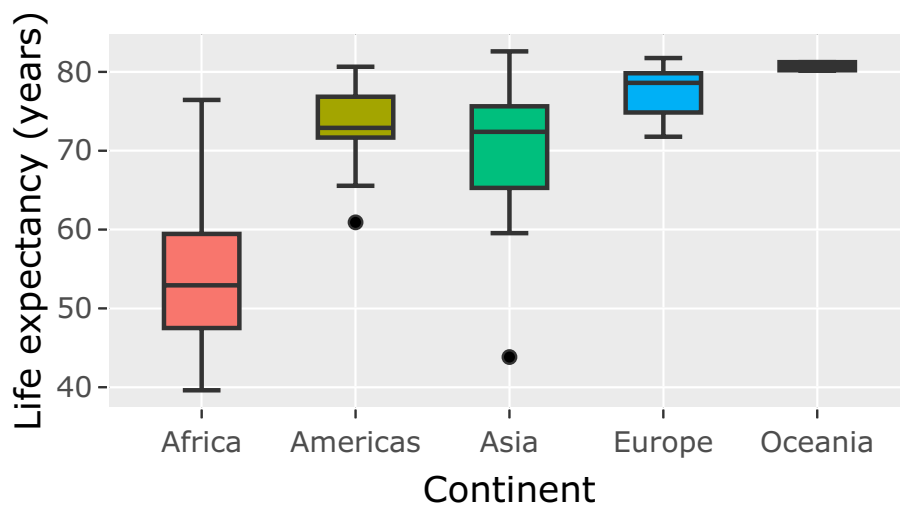
```
library(plotly) # install.packages('plotly')

scatterplot (Note: key=country shows up on rollover)
s = ggplot(g, aes(x=gdpPercap, y=lifeExp, key=country)) +
 geom_point()
ggplotly(s)
```



```
boxplot
ggplotly(b)
```

Life Expectancy by Continent for 2007

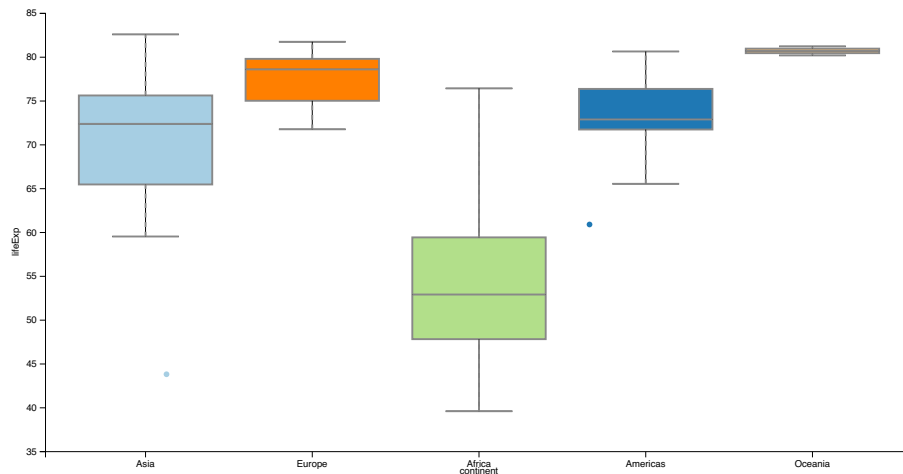


**Your Turn:** Expand the interactive scatterplot to include all the other bells and whistles of the previous plot in one continuous set of code (no in between setting of s).

### 3.1.3 Interactive: Exploding Boxplot

```
library(explodingboxplotR) # devtools::install_github('timelyportfolio/explodingboxplo

exploding_boxplot(g,
 y = 'lifeExp',
 group = 'continent',
 color = 'continent',
 label = 'country')
```



### 3.1.4 Interactive: Motion Plot

The `googleVis` package ports most of the Google charts functionality.

For every R chunk must set option `results='asis'`, and once before any googleVis plots, set `op <- options(gvis.plot.tag='chart')`.

- Rmarkdown and googleVis
- googleVis examples

```
suppressPackageStartupMessages({
 library(googleVis) # install.packages('googleVis')
})
```

```
Creating a generic function for 'toJSON' from package 'jsonlite' in package 'googleVis'
```

```
op <- options(gvis.plot.tag='chart')
```

```
m = gvisMotionChart(
 gapminder %>%
```

```
mutate(
 pop_m = pop / 1e6,
 log_gdpPercap = log(gdpPercap)),
idvar='country',
timevar='year',
xvar='log_gdpPercap',
yvar='lifeExp',
colorvar='continent',
sizevar='pop_m')
plot(m)
```

**Your Turn:** Repeat the motion chart with the country having the highest gdpPercap filtered out.

## 3.2 Map

Thematic maps **tmap**:

- tmap in a nutshell
- tmap modes: plot and interactive view

### 3.2.1 Static

```
library(sf)
library(tmap) # install.packages('tmap')

load world spatial polygons
data(World)

inspect values in World
World %>% st_set_geometry(NULL)

gapminder countries not in World. skipping for now
g %>%
 anti_join(World, by=c('country'='name')) %>%
 arrange(desc(pop))

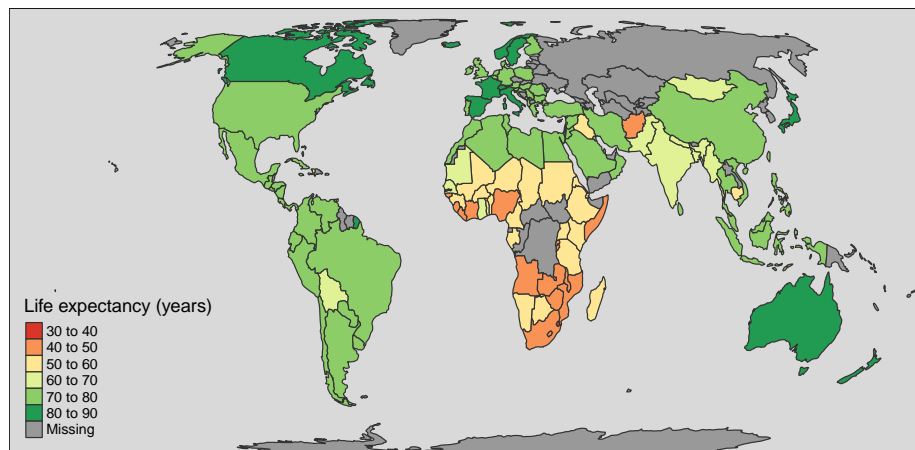
World countries not in gapminder. skipping for now
World %>%
 anti_join(g, by=c('name'='country')) %>%
 arrange(desc(pop_est)) %>%
 select(iso_a3, name, pop_est)
```

```
join gapminder data to World
World = World %>%
 left_join(g, by=c('name'='country'))

make map
m = tm_shape(World) +
 tm_polygons('lifeExp', palette='RdYlGn', id='name', title='Life expectancy (years)')
 tm_style('gray') + tm_format('World')
```

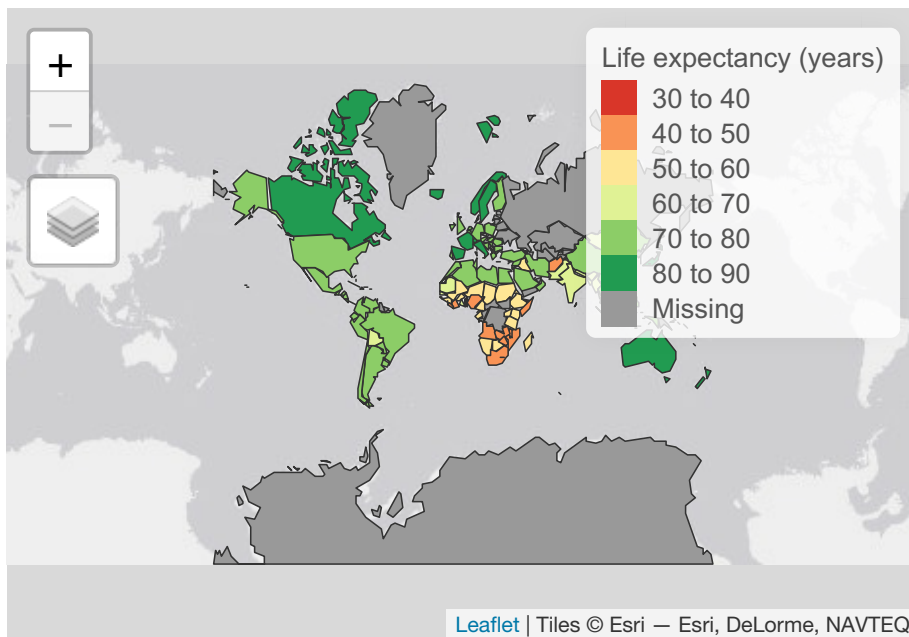
```
Warning: The argument auto.palette.mapping is deprecated. Please use midpoint
for numeric data and stretch.palette for categorical data to control the palette
mapping.
```

```
m
```



### 3.2.2 Interactive

```
show interactive map
tmap_leaflet(m)
```



### 3.3 References

- [ggplot2-cheatsheet-2.0.pdf](#)
- Interactive Plots and Maps - Environmental Informatics
- Graphs with ggplot2 - Cookbook for R
- ggplot2 Essentials - STHDA
- NEON Working with Geospatial Data





## Chapter 4

# Analyze Spatial: `sf`

### 4.1 Overview

#### Questions

- How to elegantly conduct complex spatial analysis by chaining operations?
- What is the percent area of water by region across the United States?

#### Objectives

- Use the `%>%` operator (aka “then” or “pipe”) to pass output from one function into input of the next.
- Calculate metrics on spatial attributes.
- Aggregate spatial data with metrics.
- Display a map of results.

### 4.2 Prerequisites

**R Skill Level:** Intermediate - you’ve got basics of R down.

You will use the `sf` package for vector data along with the `dplyr` package for calculating and manipulating attribute data.

```
load packages
library(tidyverse) # load dplyr, tidyr, ggplot2 packages
library(sf) # vector reading & analysis

set working directory to data folder
setwd("pathToDirHere")
```

### 4.3 States: read and plot

Similar to Lesson 9: Handling Spatial Projection & CRS in R, we'll start by reading in a polygon shapefile using the `sf` package. Then use the default `plot()` function to see what it looks like.

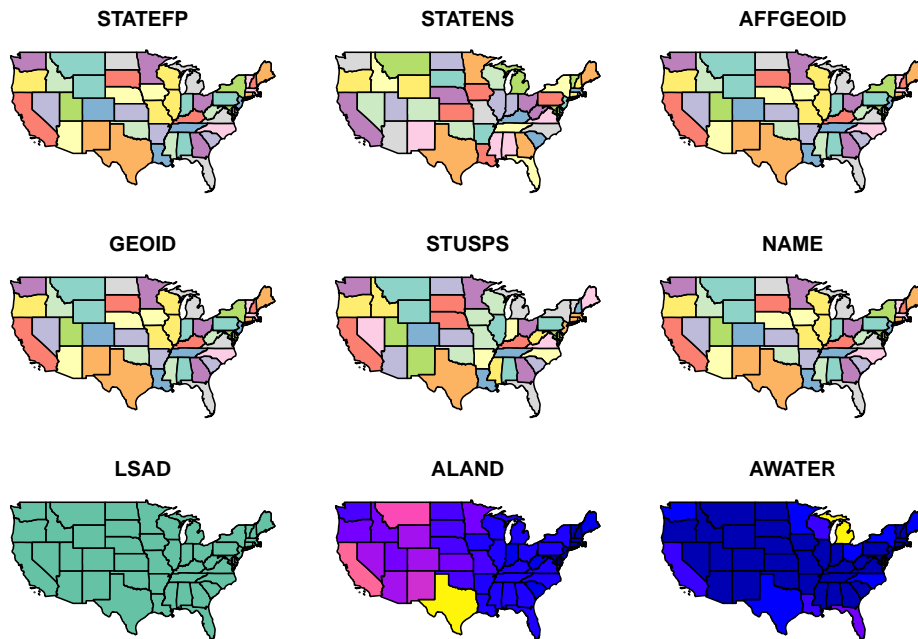
```
library(here)

states_shp <- here("data/neon-us-boundary/US-State-Boundaries-Census-2014.shp")

read in states
states <- read_sf(states_shp)

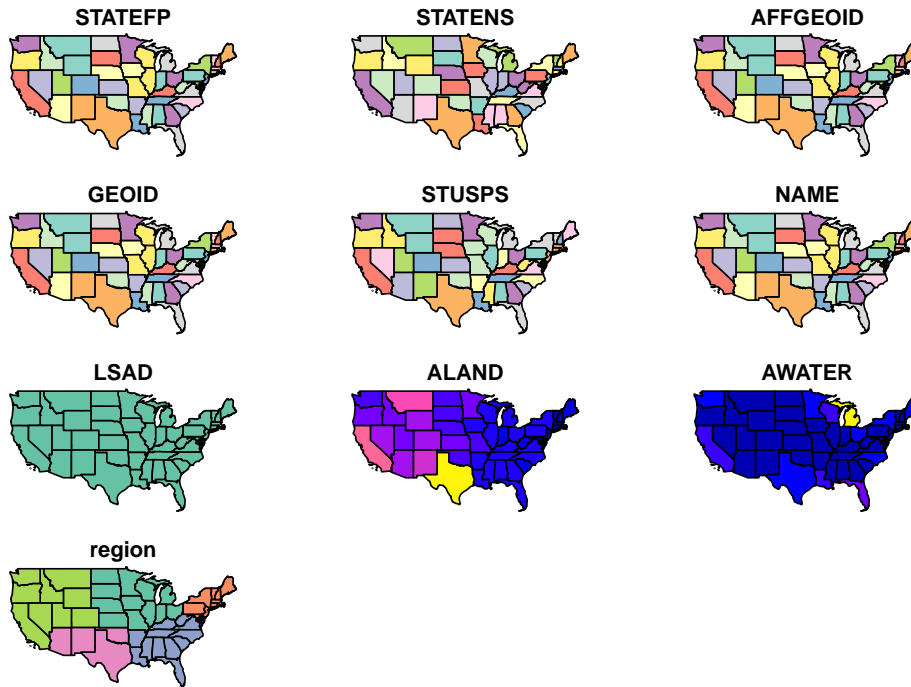
plot the states
plot(states)
```

```
Warning: plotting the first 9 out of 10 attributes; use max.plot = 10 to plot
all
```



Notice the default plot on `sf` objects outputs colored values of the first 9 of 10 columns. Use the suggestion from the warning to plot the 10th column.

```
plot 10th column
plot(states, max.plot = 10)
```



```
show columns of the data frame
names(states)
```

```
[1] "STATEFP" "STATENS" "AFFGEOID" "GEOID" "STUSPS" "NAME"
[7] "LSAD" "ALAND" "AWATER" "region" "geometry"
```

```
look at table
glimpse(states)
```

```
Rows: 58
Columns: 11
$ STATEFP <chr> "06", "11", "12", "13", "16", "17", "19", "21", "22", "24"...
$ STATENS <chr> "01779778", "01702382", "00294478", "01705317", "01779783"...
$ AFFGEOID <chr> "0400000US06", "0400000US11", "0400000US12", "0400000US13"...
$ GEOID <chr> "06", "11", "12", "13", "16", "17", "19", "21", "22", "24"...
$ STUSPS <chr> "CA", "DC", "FL", "GA", "ID", "IL", "IA", "KY", "LA", "MD"...
$ NAME <chr> "California", "District of Columbia", "Florida", "Georgia"...
$ LSAD <chr> "00", "00", "00", "00", "00", "00", "00", "00", "00", "00"...
$ ALAND <dbl> 403483823181, 158350578, 138903200855, 148963503399, 21404...
$ AWATER <dbl> 20483271881, 18633500, 31407883551, 4947080103, 2397728105...
$ region <chr> "West", "Northeast", "Southeast", "Southeast", "West", "Mi..."
$ geometry <MULTIPOLYGON [°]> MULTIPOLYGON Z (((-118.594 ..., MULTIPOLYGON ...
```

```
convert to tibble for nicer printing
as_tibble(states)
```

```
A tibble: 58 x 11
STATEFP STATENS AFFGEOID GEOID STUSPS NAME LSAD ALAND AWATER region
<chr> <chr> <chr> <chr> <chr> <chr> <chr> <dbl> <dbl> <chr>
1 06 017797~ 0400000~ 06 CA Cali~ 00 4.03e11 2.05e10 West
2 11 017023~ 0400000~ 11 DC Dist~ 00 1.58e 8 1.86e 7 North~
3 12 002944~ 0400000~ 12 FL Flor~ 00 1.39e11 3.14e10 South~
4 13 017053~ 0400000~ 13 GA Geor~ 00 1.49e11 4.95e 9 South~
5 16 017797~ 0400000~ 16 ID Idaho 00 2.14e11 2.40e 9 West
6 17 017797~ 0400000~ 17 IL Illi~ 00 1.44e11 6.20e 9 Midwe~
7 19 017797~ 0400000~ 19 IA Iowa 00 1.45e11 1.08e 9 Midwe~
8 21 017797~ 0400000~ 21 KY Kent~ 00 1.02e11 2.39e 9 South~
9 22 016295~ 0400000~ 22 LA Loui~ 00 1.12e11 2.38e10 South~
10 24 017149~ 0400000~ 24 MD Mary~ 00 2.51e10 6.98e 9 North~
... with 48 more rows, and 1 more variable: geometry <MULTIPOLYGON [°]>
```

```
names(states)
```

```
[1] "STATEFP" "STATENS" "AFFGEOID" "GEOID" "STUSPS" "NAME"
[7] "LSAD" "ALAND" "AWATER" "region" "geometry"
```

```
inspect the class(es) of the states object
class(states)
```

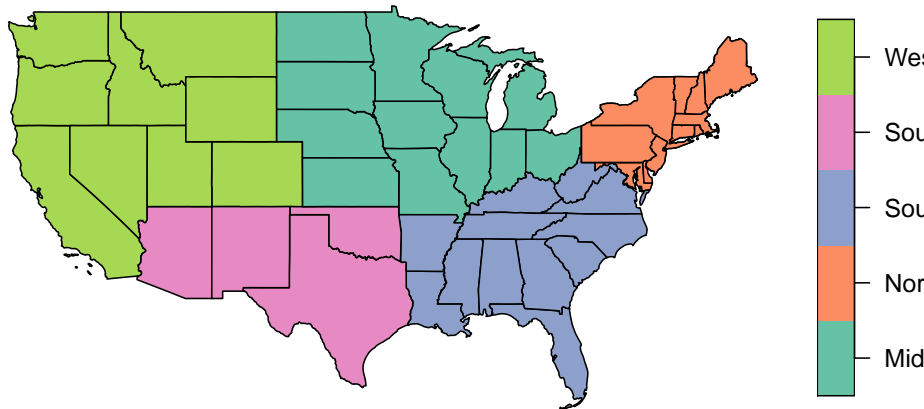
```
[1] "sf" "tbl_df" "tbl" "data.frame"
```

The class of the `states` object is both a simple feature (`sf`) as well as a data frame, which means the many useful functions available to a data frame (or “tibble”) can be applied.

To plot the column of interest, feed the “slice” of that column to the `plot()` function.

```
plot(states['region'])
```

**region**



**Question:** To motivate the spatial analysis for the rest of this lesson, you will answer this question: “*What is the percent water by region?*”

#### 4.4 Challenge: analytical steps?

Outline a sequence of analytical steps needed to arrive at the answer.

### 4.4.1 Answers

1. **Sum** the area of water (**AWATER**) and land (**ALAND**) per region.
2. **Divide** the area of water (**AWATER**) by the area of land (**ALAND**) per region to arrive at percent water.
3. Show **table** of regions sorted by percent water.
4. Show **map** of regions by percent water with a color ramp and legend.

#### 4.5 Regions: calculate % water

- Use the `%>` operator (aka “then” or “pipe”) to pass output from one function into input of the next.
  - In RStudio, see menu `Help > Keyboard Shortcuts Help` for a shortcut to the “Insert Pipe Operator”.
- Calculate metrics on spatial attributes.
  - In RStudio, see menu `Help > Cheatsheets > Data Manipulation with dplyr, tidyr`.

- Aggregate spatial data with metrics.

```
regions = states %>%
 group_by(region) %>%
 summarize(
 water = sum(AWATER),
 land = sum(ALAND)) %>%
 mutate(
 pct_water = water / land * 100 %>% round(2))

`summarise()` ungrouping output (override with `.groups` argument)
object
regions

Simple feature collection with 5 features and 4 fields
geometry type: GEOMETRY
dimension: XYZ
bbox: xmin: -124.7258 ymin: 24.49813 xmax: -66.9499 ymax: 49.38436
z_range: zmin: 0 zmax: 0
geographic CRS: WGS 84
A tibble: 5 x 5
region water land geometry pct_water
* <chr> <dbl> <dbl> <GEOMETRY [°]> <dbl>
1 Midwest 1.84e11 1.94e12 MULTIPOLYGON Z (((-87.80048 42.49192 0,~ 9.49
2 Northe~ 1.09e11 8.69e11 MULTIPOLYGON Z (((-76.04621 38.02553 0,~ 12.5
3 Southe~ 1.04e11 1.36e12 MULTIPOLYGON Z (((-81.81169 24.56874 0,~ 7.61
4 Southw~ 2.42e10 1.46e12 POLYGON Z ((-94.48587 33.63787 0, -94.4~ 1.66
5 West 5.76e10 2.43e12 MULTIPOLYGON Z (((-104.0532 41.00141 0,~ 2.37
```

Notice the geometry in the column. To remove the geometry column pipe to `st_set_geometry(NULL)`. To arrange in descending order use `arrange(desc(pct_water))`.

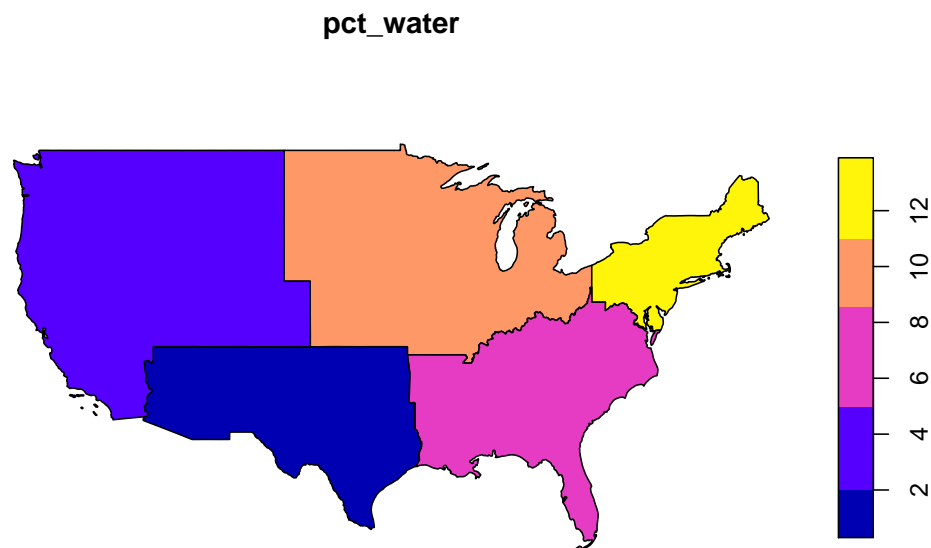
```
table
regions %>%
 st_set_geometry(NULL) %>%
 arrange(desc(pct_water))

A tibble: 5 x 4
region water land pct_water
<chr> <dbl> <dbl> <dbl>
1 Northeast 108922434345 869066138232 12.5
2 Midwest 184383393833 1943869253244 9.49
3 Southeast 103876652998 1364632039655 7.61
4 West 57568049509 2432336444730 2.37
5 Southwest 24217682268 1462631530997 1.66
```

## 4.6 Regions: plot

Now plot the regions.

```
plot, default
plot(regions['pct_water'])
```

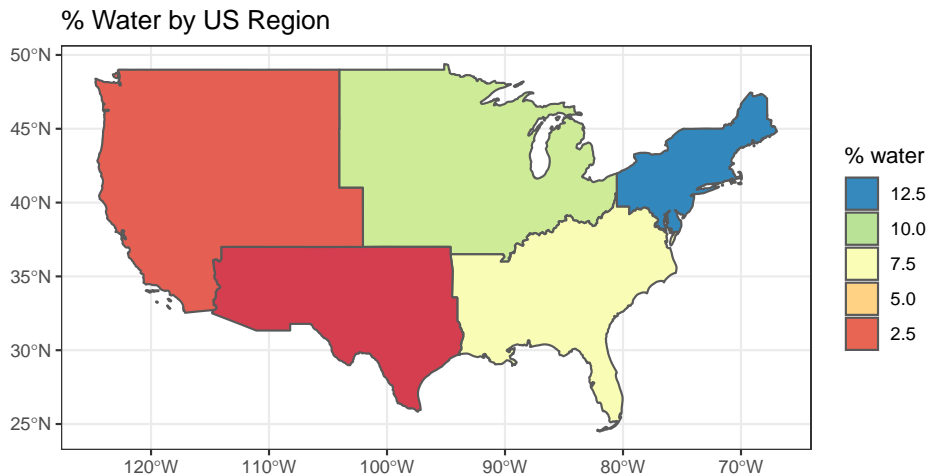


## 4.7 Regions: ggplot

The `ggplot2` library can visualise `sf` objects.

- In RStudio, see menu Help > Cheatsheets > Data Visualization with `ggplot2`.

```
plot, ggplot
ggplot(regions) +
 geom_sf(aes(fill = pct_water)) +
 scale_fill_distiller(
 "pct_water", palette = "Spectral", direction=1,
 guide = guide_legend(title = "% water", reverse=T)) +
 theme_bw() +
 ggtitle("% Water by US Region")
```



## 4.8 Regions: recalculate area

So far you've used the `ALAND` column for area of the state. But what if you were not provided the area and needed to calculate it? Because the `states` are in geographic coordinates, you'll need to either transform to an equal area projection and calculate area, or use geodesic calculations. Thankfully, the `sf` library provides area calculations with the `st_area()` and uses the `geosphere::distGeo()` to perform geodesic calculations (ie trigonometric calculation accounting for the spheroid nature of the earth). Since the `states` data has the unusual aspect of a `z` dimension, you'll need to first remove that with the `st_zm()` function.

```
library(geosphere)
library(units)

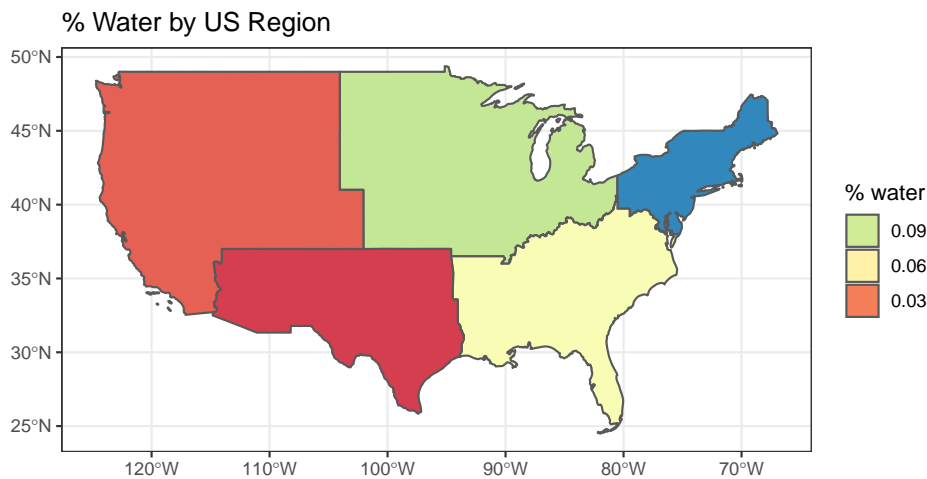
regions = states %>%
 mutate(
 water_m2 = AWATER %>% set_units(m^2),
 land_m2 = geometry %>% st_zm() %>% st_area()) %>%
 group_by(region) %>%
 summarize(
 water_m2 = sum(water_m2),
 land_m2 = sum(land_m2)) %>%
 mutate(
 pct_water = water_m2 / land_m2)

table
regions %>%
 st_set_geometry(NULL) %>%
 arrange(desc(pct_water))
```



```
A tibble: 5 x 4
region water_m2 land_m2 pct_water
<chr> [m^2] [m^2] [1]
1 Northeast 108922434345 9.117041e+11 0.11947126
2 Midwest 184383393833 1.987268e+12 0.09278233
3 Southeast 103876652998 1.427079e+12 0.07278971
4 West 57568049509 2.467170e+12 0.02333363
5 Southwest 24217682268 1.483765e+12 0.01632178

plot, ggplot
ggplot(regions) +
 geom_sf(aes(fill = as.numeric(pct_water))) +
 scale_fill_distiller(
 "pct_water", palette = "Spectral", direction=1,
 guide = guide_legend(title = "% water", reverse=T)) +
 theme_bw() +
 ggtitle("% Water by US Region")
```



## 4.9 Challenge: project & recalculate area

Use `st_transform()` with a USA Contiguous Albers Equal Area Conic Projection that minimizes distortion, and then calculate area using the `st_area()` function.

## 4.9.1 Answers

```
library(geosphere)
library(units)

Proj4 of http://spatialreference.org/ref/esri/usa-contiguous-albers-equal-area-conic
crs_usa = '+proj=aea +lat_1=29.5 +lat_2=45.5 +lat_0=37.5 +lon_0=-96 +x_0=0 +y_0=0 +ellps=GRS80'

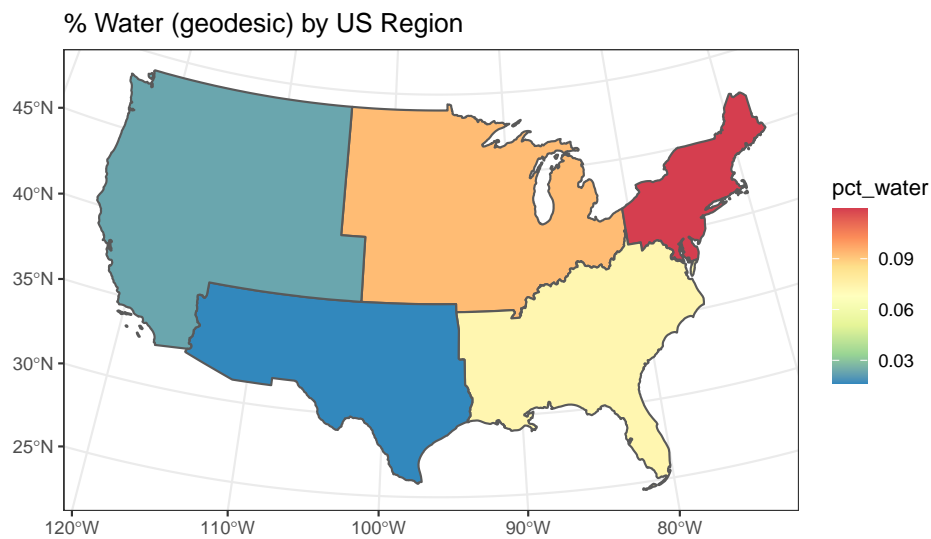
regions = states %>%
 st_transform(crs_usa) %>%
 mutate(
 water_m2 = AWATER %>% set_units(m^2),
 land_m2 = geometry %>% st_zm() %>% st_area()) %>%
 group_by(region) %>%
 summarize(
 water_m2 = sum(water_m2),
 land_m2 = sum(land_m2)) %>%
 mutate(
 pct_water = water_m2 / land_m2)
```

```
`summarise()` ungrouping output (override with `.groups` argument)

table
regions %>%
 st_set_geometry(NULL) %>%
 arrange(desc(pct_water))
```

```
A tibble: 5 x 4
region water_m2 land_m2 pct_water
<chr> [m^2] [m^2] [1]
1 Northeast 108922434345 9.117031e+11 0.11947138
2 Midwest 184383393833 1.987266e+12 0.09278246
3 Southeast 103876652998 1.427078e+12 0.07278973
4 West 57568049509 2.467167e+12 0.02333367
5 Southwest 24217682268 1.483758e+12 0.01632185

plot, ggplot
ggplot(regions) +
 geom_sf(aes(fill = as.numeric(pct_water))) +
 scale_fill_distiller("pct_water", palette = "Spectral") +
 theme_bw() +
 ggtitle("% Water (geodesic) by US Region")
```



## 4.10 Key Points

- The `sf` package can take advantage of chaining spatial operations using the `%>%` operator.
- Data manipulation functions in `dplyr` such as `group_by()`, `summarize()` and `mutate()` work on `sf` objects.
- Area can be calculated a variety of ways. Geodesic is preferred if starting with geographic coordinates (vs projected).



## Chapter 5

# Interactive Map: leaflet

### 5.1 Overview

#### Questions

- How do you generate interactive plots of spatial data to enable pan, zoom and hover/click for more detail?

#### Objectives

Learn variety of methods for producing interactive spatial output using libraries:

- `plotly`: makes any `ggplot2` object interactive
- `mapview`: quick view of any spatial object
- `leaflet`: full control over interactive map

### 5.2 Things You'll Need to Complete this Tutorial

**R Skill Level:** Intermediate - you've got basics of R down.

We will continue to use the `sf` and `raster` packages and introduce the `plotly`, `mapview`, and `leaflet` packages in this tutorial.

```
load packages
library(tidyverse) # loads dplyr, tidyr, ggplot2 packages
library(sf) # simple features package - vector
library(raster) # raster
library(plotly) # makes ggplot objects interactive
library(mapview) # quick interactive viewing of spatial objects
```

```
library(leaflet) # interactive maps

set working directory to data folder
setwd("pathToDirHere")
```

### 5.3 States: ggplot2

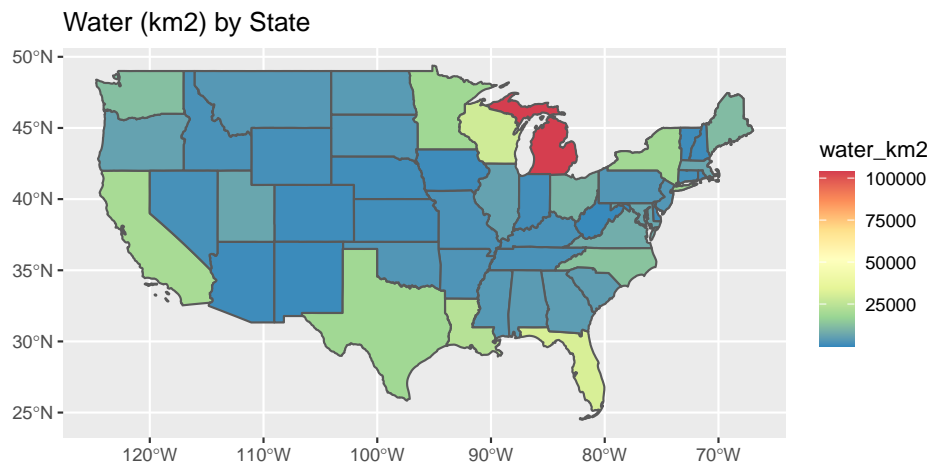
Recreate the ggplot object from Lesson ?? and save into a variable for subsequent use with the plotly package.

```
library(here)

states_shp <- here("data/neon-us-boundary/US-State-Boundaries-Census-2014.shp")

read in states
states <- read_sf(states_shp) %>%
 st_zm() %>%
 mutate(
 water_km2 = (AWATER / (1000*1000)) %>% round(2))

plot, ggplot
g = ggplot(states) +
 geom_sf(aes(fill = water_km2)) +
 scale_fill_distiller("water_km2", palette = "Spectral") +
 ggtitle("Water (km2) by State")
g
```



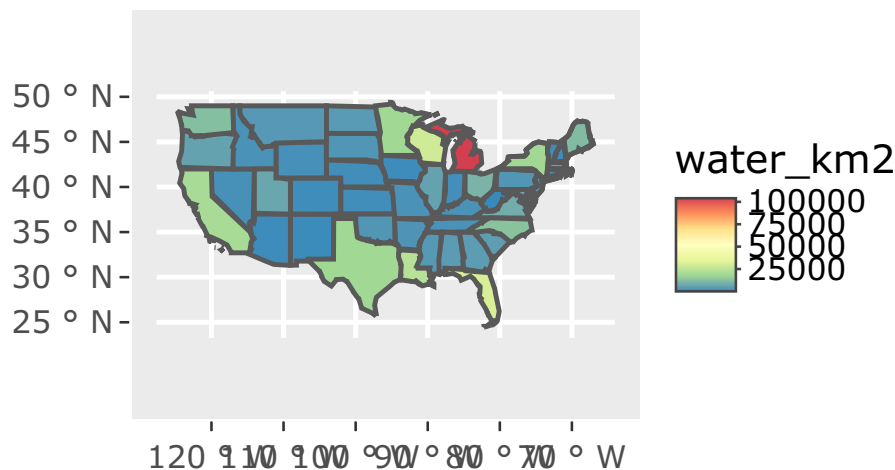
## 5.4 States: plotly

The `plotly::ggplotly()` function outputs a ggplot into an interactive window capable of pan, zoom and identify.

```
library(plotly)
```

```
ggplotly(g)
```

### Water (km2) by State

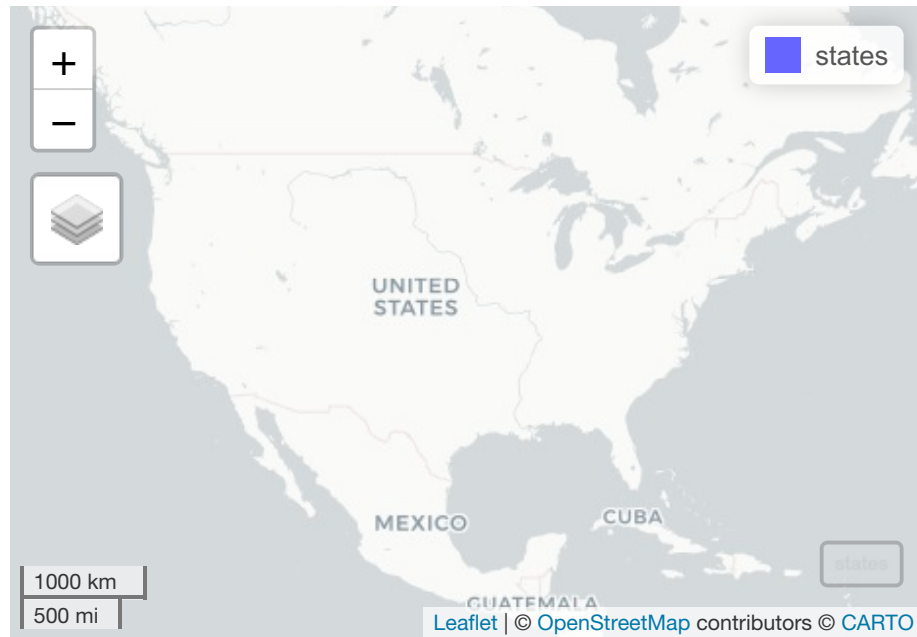


## 5.5 States: mapview

The `mapview::mapview()` function can work for a quick view of the data, providing choropleths, background maps and attribute popups. Performance varies on the object and customization can be tricky.

```
library(mapview)
```

```
simple view with popups
mapview(states)
```



```
coloring and layering
mapview(states, zcol='water_km2', burst='STUSPS')
```



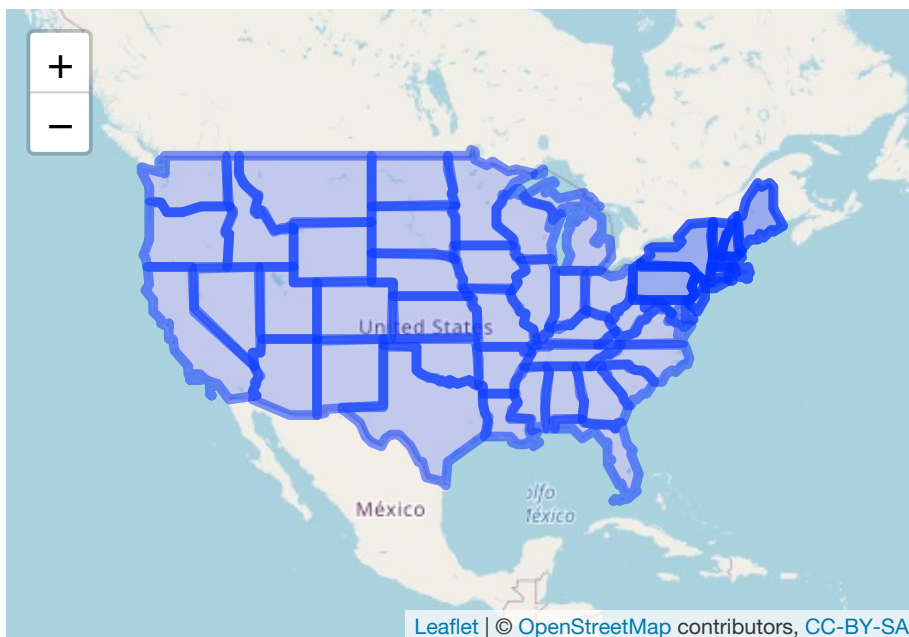


## 5.6 States: leaflet

The `leaflet` package offers a robust set of functions for viewing vector and raster data, although requires more explicit functions.

```
library(leaflet)

leaflet(states) %>%
 addTiles() %>%
 addPolygons()
```



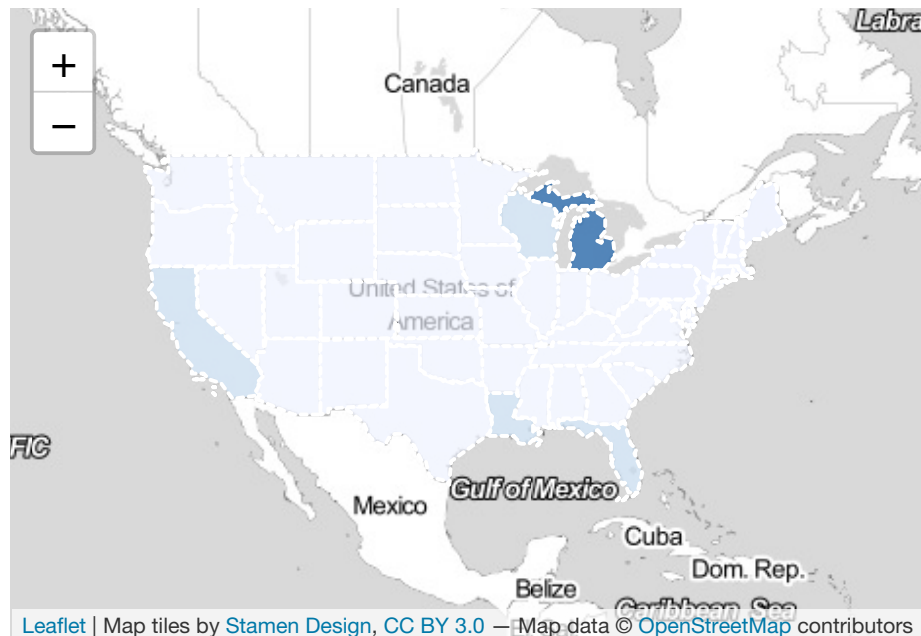
### 5.6.1 Choropleth

Drawing from the documentation from Leaflet for R - Choropleths, we can construct a pretty choropleth.

```
pal <- colorBin("Blues", domain = states$water_km2, bins = 7)

leaflet(states) %>%
 addProviderTiles("Stamen.TonerLite") %>%
 addPolygons(
 # fill
 fillColor = ~pal(water_km2),
 fillOpacity = 0.7,
```

```
line
dashArray = "3",
weight = 2,
color = "white",
opacity = 1,
interaction
highlight = highlightOptions(
 weight = 5,
 color = "#666",
 dashArray = "",
 fillOpacity = 0.7,
 bringToFront = TRUE))
```



### 5.6.2 Popups and Legend

Adding a legend and popups requires a bit more work, but achieves a very aesthetically and functionally pleasing visualization.

```
library(htmltools)
library(scales)

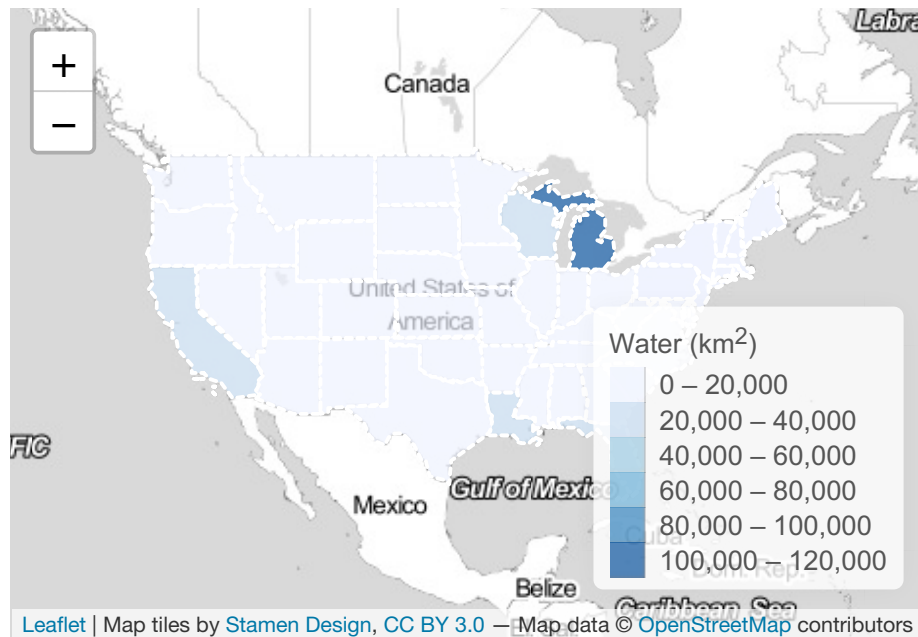
labels <- sprintf(
 "%s
 water: %s km²",
 states$NAME, comma(states$water_km2)) %>%
```

```

lapply(HTML)

leaflet(states) %>%
 addProviderTiles("Stamen.TonerLite") %>%
 addPolygons(
 # fill
 fillColor = ~pal(water_km2),
 fillOpacity = 0.7,
 # line
 dashArray = "3",
 weight = 2,
 color = "white",
 opacity = 1,
 # interaction
 highlight = highlightOptions(
 weight = 5,
 color = "#666",
 dashArray = "",
 fillOpacity = 0.7,
 bringToFront = TRUE),
 label = labels,
 labelOptions = labelOptions(
 style = list("font-weight" = "normal", padding = "3px 8px"),
 textsize = "15px",
 direction = "auto")) %>%
 addLegend(
 pal = pal, values = ~water_km2, opacity = 0.7, title = HTML("Water (km²)"),
 position = "bottomright")

```



## 5.7 Challenge: leaflet for regions

Use Lesson ?? final output to create a regional choropleth with legend and popups for percent water by region.

### 5.7.1 Answers

```
regions = states %>%
 group_by(region) %>%
 summarize(
 water = sum(AWATER),
 land = sum(ALAND)) %>%
 mutate(
 pct_water = (water / land * 100) %>% round(2))

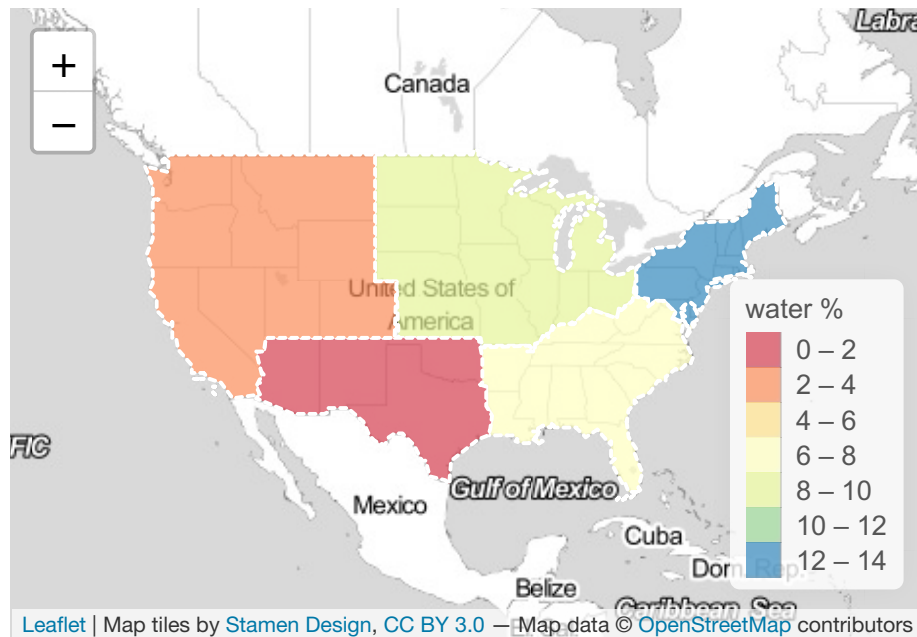
`summarise()` ungrouping output (override with `.groups` argument)

pal <- colorBin("Spectral", domain = regions$pct_water, bins = 5)

labels <- sprintf(
 "%s
water: %s%%",
 regions$region, comma(regions$pct_water)) %>%
```

```
lapply(HTML)

leaflet(regions) %>%
 addProviderTiles("Stamen.TonerLite") %>%
 addPolygons(
 # fill
 fillColor = ~pal(pct_water),
 fillOpacity = 0.7,
 # line
 dashArray = "3",
 weight = 2,
 color = "white",
 opacity = 1,
 # interaction
 highlight = highlightOptions(
 weight = 5,
 color = "#666",
 dashArray = "",
 fillOpacity = 0.7,
 bringToFront = TRUE),
 label = labels,
 labelOptions = labelOptions(
 style = list("font-weight" = "normal", padding = "3px 8px"),
 textsize = "15px",
 direction = "auto")) %>%
 addLegend(
 pal = pal, values = ~pct_water, opacity = 0.7, title = "water %",
 position = "bottomright")
```



## 5.8 Raster: leaflet

TODO: show raster overlay using NEON raster dataset example

## 5.9 Key Points

- Interactive maps provide more detail for visual investigation, including use of background maps, but is only relevant in a web context.
- Several packages exist for providing interactive views of data.
- The `plotly::ggplotly()` function works quickly if you already have a `ggplot` object, which is best for static output.
- The `mapview::mapview()` function can work for a quick view of the data, providing choropleths, background maps and attribute popups. Performance varies on the object and customization can be tricky.
- The `leaflet` package provides a highly customizable set of functions for rendering of interactive choropleths with background maps, legends, etc.

## Appendix A

# Appendix Shiny Google Auth

- dkulp2/Google-Sign-In: Simple Example of Shiny App Using Google Sign-In API
- You'll need to change from `http://127.0.0.1:7445/` to `http://localhost:7445`, otherwise you'll get:

```
Authorization Error
Error 400: invalid_request
Permission denied to generate login hint for target domain.
```

- You'll need to run the app on a specific port using `shiny::runApp(port=7445)`, otherwise you'll get something like:

```
Authorization Error
Error 400: redirect_uri_mismatch
The JavaScript origin in the request, http://localhost:5779, does not match the ones authori
```