Food and Agriculture Organization of the United Nations

中国援助 CHINA AID FOR SHARED FUTURE

AFACI Asian Food & Agriculture Cooperation Initiative

Rural Development Administration

EduSoils

R Basics

Essentials for Getting Started

GSP-Secretariat

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GLOBAL SOIL PARTNERSHIP

What is R?

R: Engine	RStudio: Dashboard

FIGURE 1.1: Analogy of difference between R and RStudio.

https://moderndive.netlify.app/1-getting-started.html#r-rstudio

What is R and RStudio?

- R is an object-based programming language that runs computations
- RStudio is an integrated development environment (IDE) that provides an interface by adding many convenient features and tools

So just as the way of having access to a speedometer, rearview mirrors, and a navigation system makes driving much easier, using RStudio's interface makes using R much easier as well

https://moderndive.netlify.app/1-getting-started.html#r-rstudio

Why R?

- **R** is **free** to install, use, update, clone, modify, redistribute, even sell.
- It works in all operative systems.
- R's strong **package ecosystem** and **charting benefits**
- Clean, analyse, plot, and communicate all from the **same place**
- Keep track of your steps -> **Reproducibility**
- Reduce processing time -> **Automation**
- Everything you **do** in the analysis, from deleting outliers to interpreting results, is contained in your code
- State-of-the-art **graphics**
- Maintained by its large community: great support!
- Most tools for **digital soil mapping** are written in R

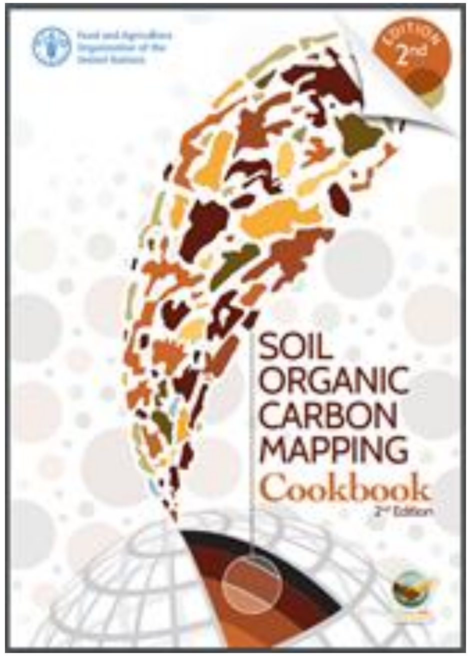
Additional learning material

Using R for Digital Soil Mapping
https://link.springer.com/book/10.1007/978-3-319-44327-0#:~:text=This%20book%20describes%20and%20provides,and%20spatial%20data%20in%20R.

Soil Organic Carbon Cookbook
http://www.fao.org/3/I8895EN/i8895en.pdf

Introduction to the R Project for Statistical Computing for use at ITC by D G Rossiter
https://cran.r-project.org/doc/contrib/Rossiter-RIntro-ITC.pdf

Youtube channel: MarinStatsLectures- R Programming & Statistics
https://www.youtube.com/channel/UCaNIxVagLhqupvUiDK01Mgg



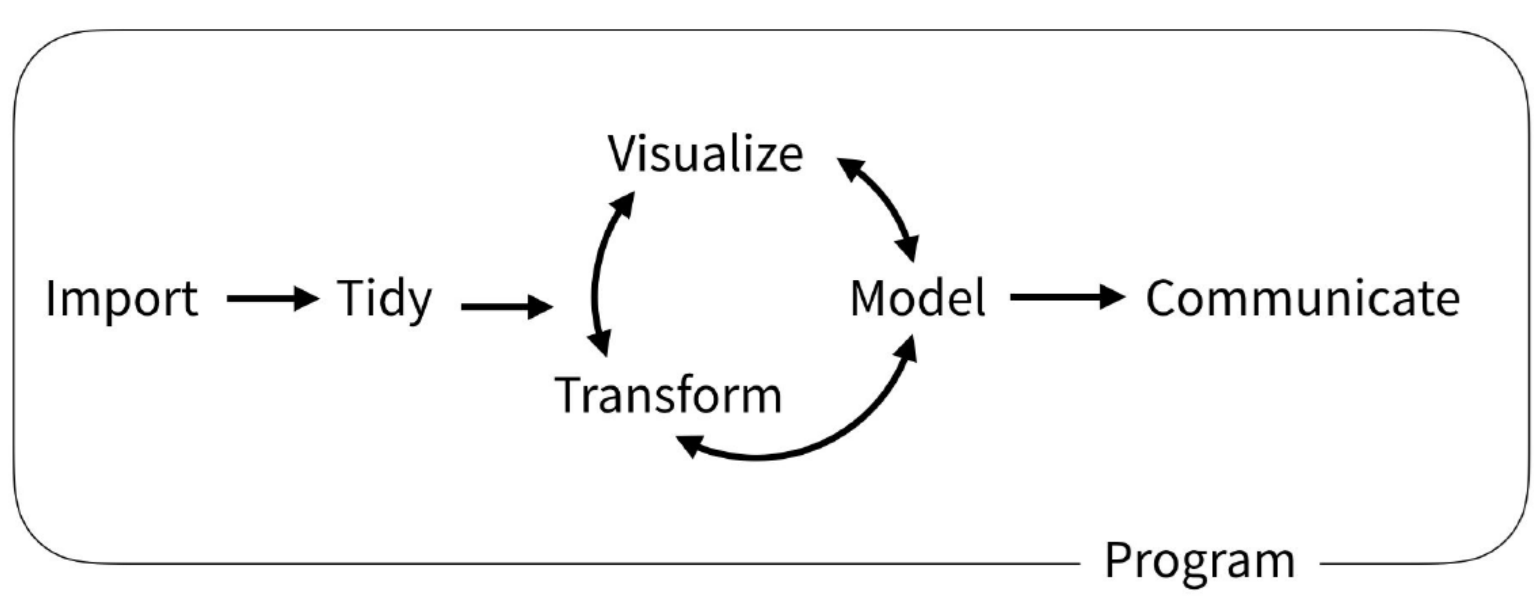
Installation

1. Download and install R and Rtools
   https://cloud.r-project.org/ https://cran.r-project.org/bin/windows/Rtools/rtools42/rtools.html

1. Download and install RStudio
   https://www.rstudio.com/products/rstudio/download/

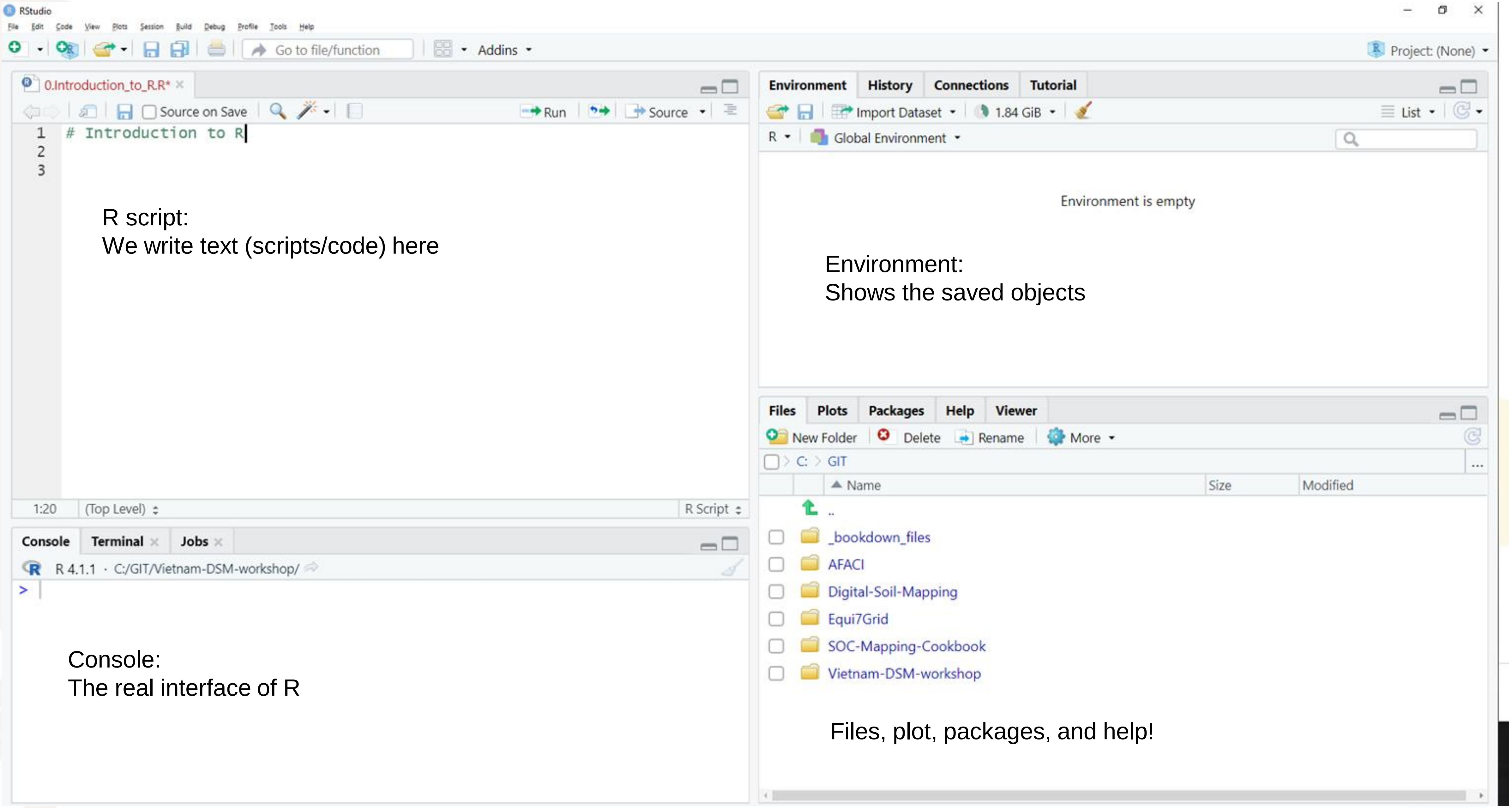
R: Do not open this	RStudio: Open this

General workflow in R

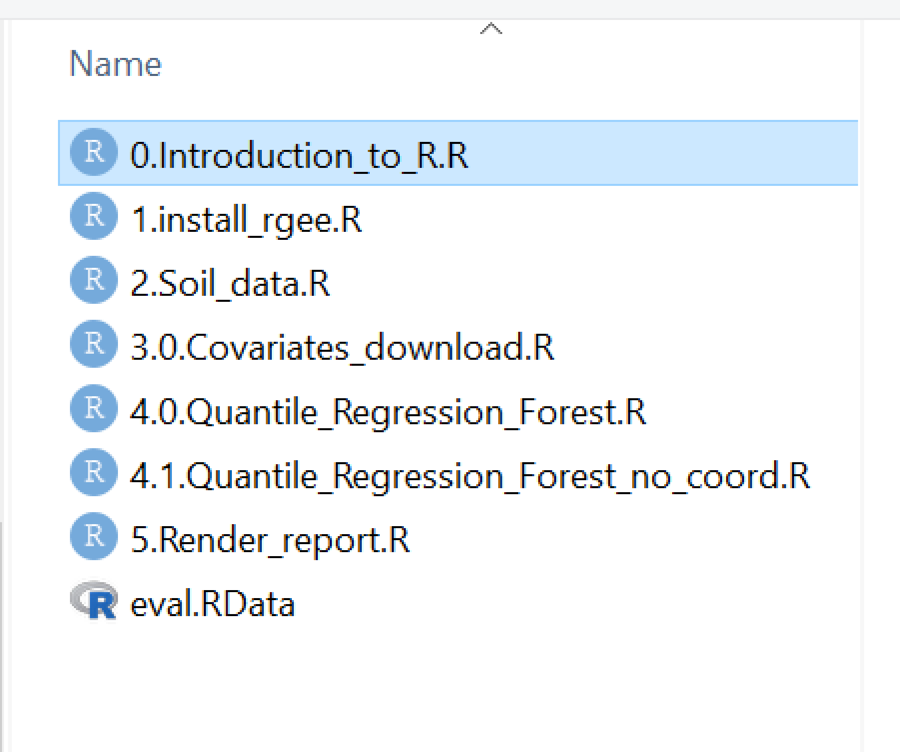


https://r4ds.had.co.nz/explore-intro.html

RStudio interface



Open the script 0.Introduction_to_R.R



Main parts of R syntax

- Functions: mean(), read_csv(), plot()
  - Arguments in functions: mean(x = 1:10) which is the same than mean(1:10)
- Objects
  - Vectors: concatenated values
  - Dataframes: spreadsheets
  - Lists: group of any objects, like a folder
  - Others
- Type of data in objects
  - Numeric: 1, 2, 3, 4.5, 6.02
  - Character: “a”, “b”, “1”, “this is a character”
  - Factors: characters with levels
- Packages:
  - Add-ons that contain functions for an specific use: “base”, “tydiverse”, “raster” , etc.

Main parts of R syntax

- Operators
  - Assign: <- (=)
  - Equal: a == b
  - Different: a != b
  - Column: $, dataframe$column_1
  - Subset: [],
    - vector[1] is the first element of the vector
    - Dataframe[row,column], e.g. dataframe[1,] is the first row of the dataframe, dataframe[,1:5] are the first columns of the dataframe
    - List[[1]] is the first object of the list
  - Concatenate functions: %>% (pipe symbol)
  - Other symbols with expected behavior: +, -, *, /, >, <, ^ (power), & (and), | (or)

- R is case sensitive
  - “THIS” is not the same than “this”

- Many packages -> many different ways to do the same
  - Some packages require an specific syntax, such as ggplot2

Other logical operators

- %in% allows you to verify if an element is part of another object

Logical and boolean operators to use with filter()

==	<	<=	is.na()	%in%	|	xor()
!=	>	>=	!is.na()	!	&	

See **?base::Logic** and **?Comparison** for help.

TRUE

FALSE

TRUE

We will use the following packages

- Tabular-data management: **tidyverse**
- Plotting:
  - Tabular data: **ggplot2**
  - Maps: **mapview** and **tmap**
- For spatial data
  - Rasters: **raster** and **terra**
  - Shape files: **sf** and **terra**
  - Access remote sensing data: **rgee**
  - Other GIS tools: **rgdal**
- Modelling: **caret**

Tidyverse

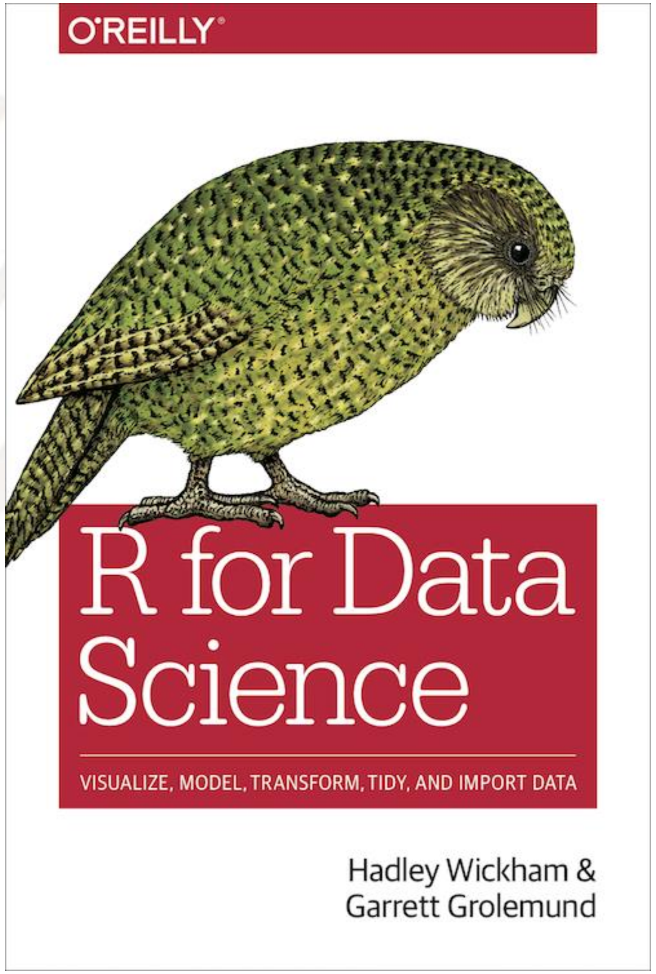
https://www.tidyverse.org/

The tidyverse is an opinionated collection of R packages designed for data science. All packages share an underlying design philosophy, grammar, and data structures.

Tidyverse

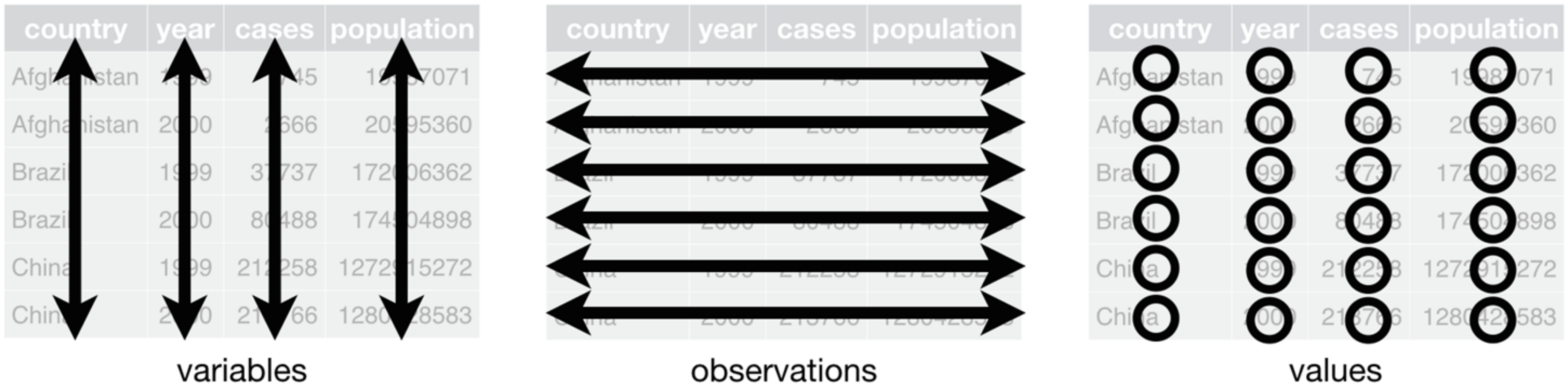
https://r4ds.had.co.nz/

Chapter 5:
Data transformation



Tidyverse

- Concatenate function with (`%>%`).
- Pick variables by their names (`select()`).
- Pick observations by their values (`filter()`).
- Create new variables with functions of existing variables (`mutate() & transmute()`).
- Group table by key variable(s) (`group_by()`).
- Collapse many values down to a single summary (`summarise()`).
- Reshape the structure of the table (`pivot_longer(), pivot_wider()`).
- Join relational tables (`left_join(), right_join(), full_join()`).

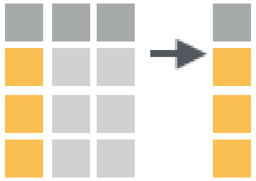


Tidyverse: Pipe %>%

- Data
  - %>%
    - subproduct 1
      - %>%
        - subproduct 2
          - %>%
            - result

Tidyverse: select()

- Pick variables by their names (`select()`).



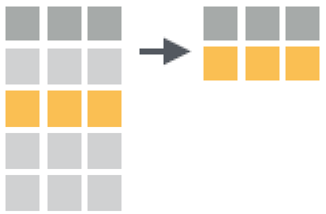
select(.data, …**)** Extract columns as a table.
select(mtcars, mpg, wt)

Exercise

- Select variables id_prof, id_hor, top, bottom, ph_h2o, cec and save as a new object called dat_1

Tidyverse: filter()

- Pick observations by their values (`filter()`).



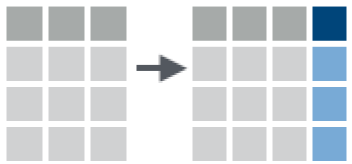
filter(.data, …, .preserve = FALSE) Extract rows that meet logical criteria.
filter(mtcars, mpg > 20)

Exercise

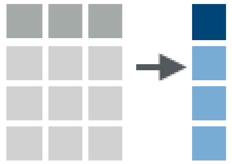
- Filter observations from dat_1 with more than 50 cmolc/kg cec and save it as dat_2

Tidyverse: mutate()

- Create new variables with functions of existing variables (`mutate()` & `transmute()`).



mutate(.data, …, .keep = "all", .before = NULL, .after = NULL) Compute new column(s). Also **add_column(), add_count(),** and **add_tally().**
mutate(mtcars, gpm = 1 / mpg)



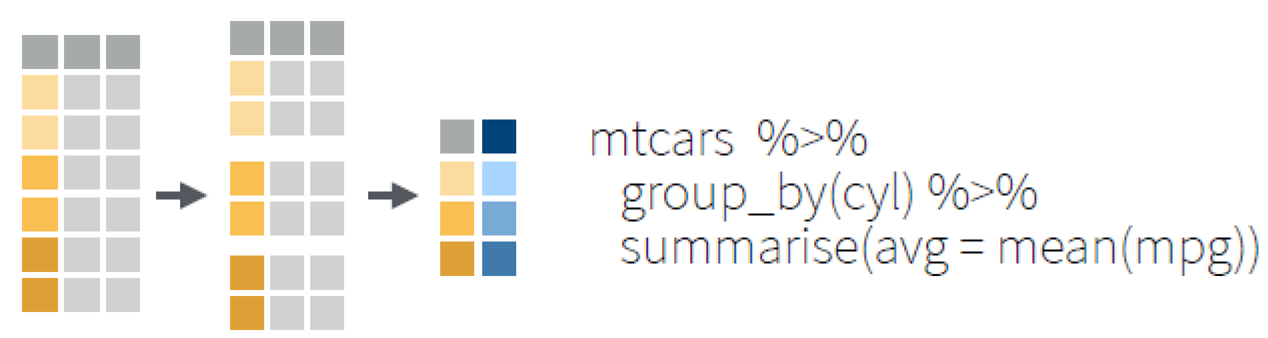
transmute(.data, …) Compute new column(s), drop others.
transmute(mtcars, gpm = 1 / mpg)

Exercise

- Create a column with the thickness of the horizon. Column name "thickness". Save the new object as dat_3. What is the difference with transmute?

Tidyverse: group_by() & summarise()

- Group table by key variable(s) (`group_by()`).
- Collapse many values down to a single summary (`summarise()`).



Exercise

- Compute the mean of pH and mean of cec for each soil profile (pid) using dat_3 as input. Save as dat_4

Tidyverse: pivot

- Reshape the structure of the table (`pivot_longer()`, `pivot_wider()`).

Exercise

- Using dat_3, put the <u>names of the variables</u> ph_h2o, cec and thickness in the column soil_property, and the values of the soil property in the value column. Keep the rest of the table. Save in dat_5

table4a

country	1999	2000
A	0.7K	2K
B	37K	80K
C	212K	213K

→

country	year	cases
A	1999	0.7K
B	1999	37K
C	1999	212K
A	2000	2K
B	2000	80K
C	2000	213K

pivot_longer(data, cols, names_to = "name", values_to = "value", values_drop_na = FALSE**)**

"Lengthen" data by collapsing several columns into two. Column names move to a new names_to column and values to a new values_to column.

pivot_longer(table4a, cols = 2:3, names_to ="year", values_to = "cases")

table2

country	year	type	count
A	1999	cases	0.7K
A	1999	pop	19M
A	2000	cases	2K
A	2000	pop	20M
B	1999	cases	37K
B	1999	pop	172M
B	2000	cases	80K
B	2000	pop	174M
C	1999	cases	212K
C	1999	pop	1T
C	2000	cases	213K
C	2000	pop	1T

→

country	year	cases	pop
A	1999	0.7K	19M
A	2000	2K	20M
B	1999	37K	172M
B	2000	80K	174M
C	1999	212K	1T
C	2000	213K	1T

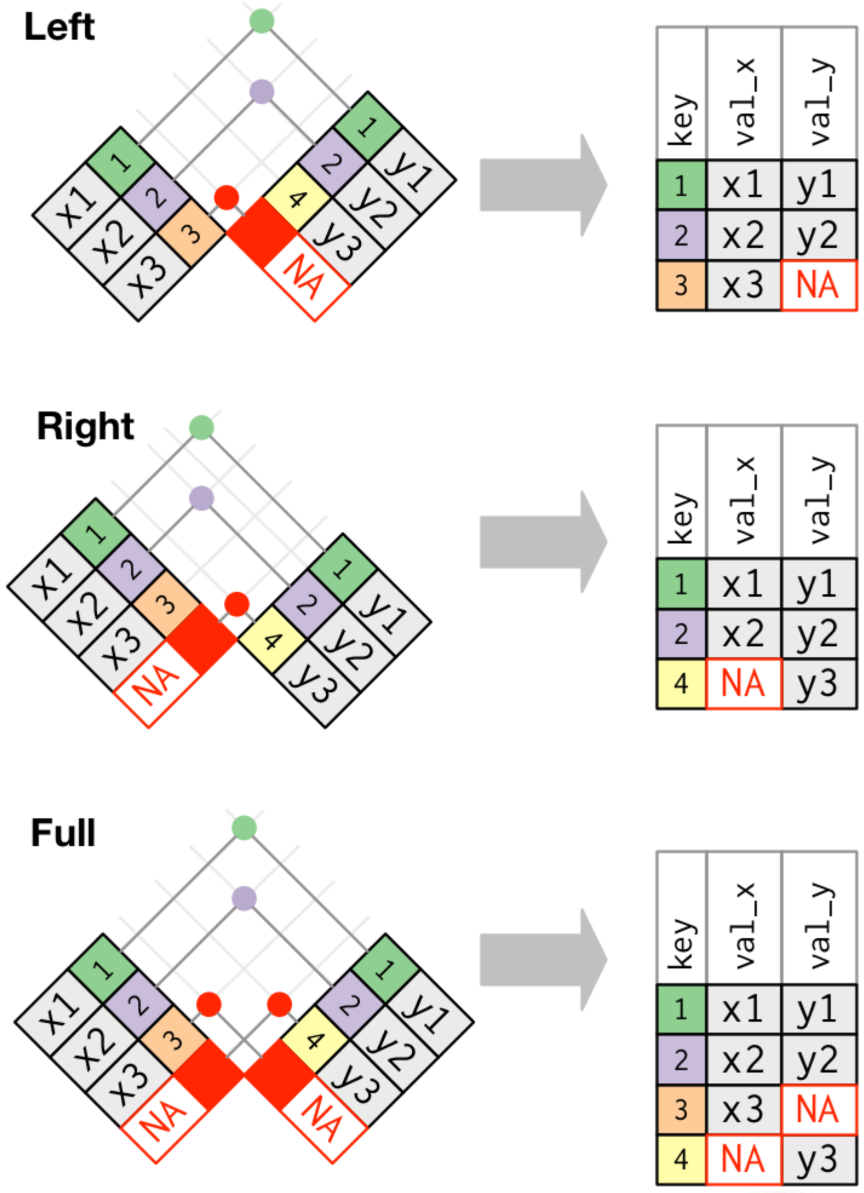
pivot_wider(data, names_from = "name", values_from = "value"**)**

The inverse of pivot_longer(). "Widen" data by expanding two columns into several. One column provides the new column names, the other the values.

pivot_wider(table2, names_from = type, values_from = count)

Tidyverse: join

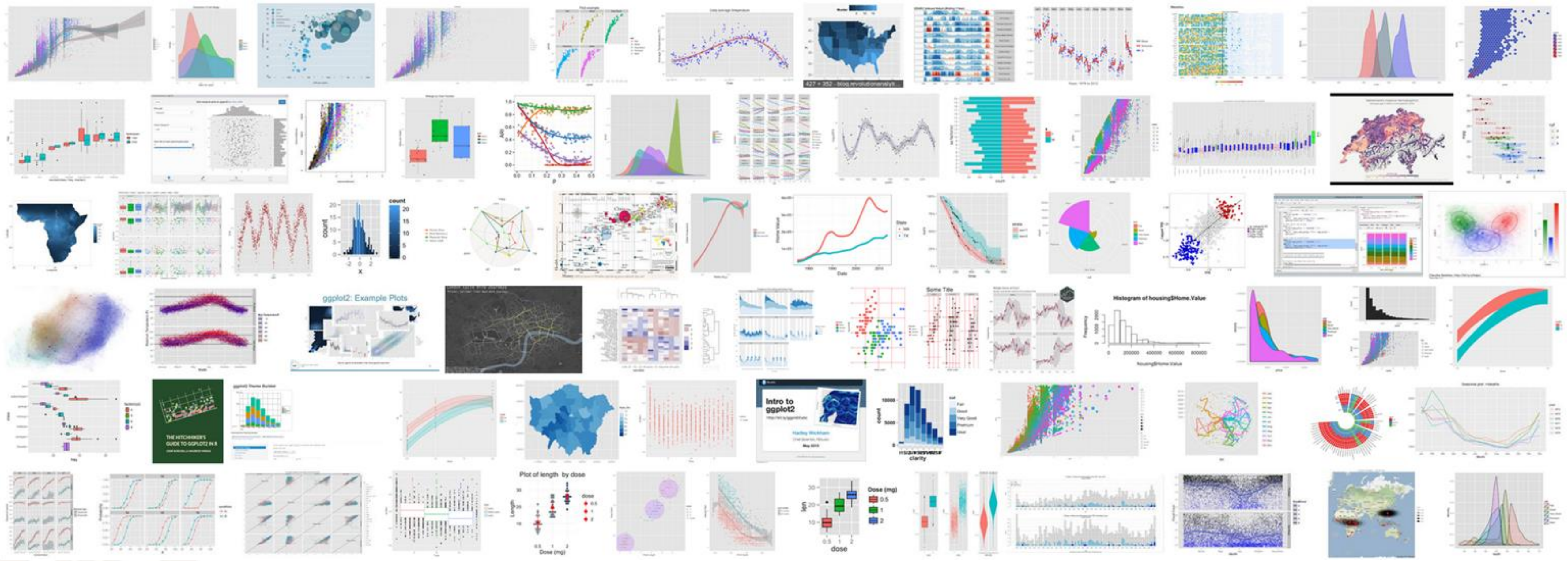
- Join relational tables (`left_join()`, `right_join()`, `full_join()`)



Exercise

- Load site.csv (in 01-Data folder) and join its columns with dat_3. Use pid as key. Save the result as dat_6

Data Visualization with ggplot2



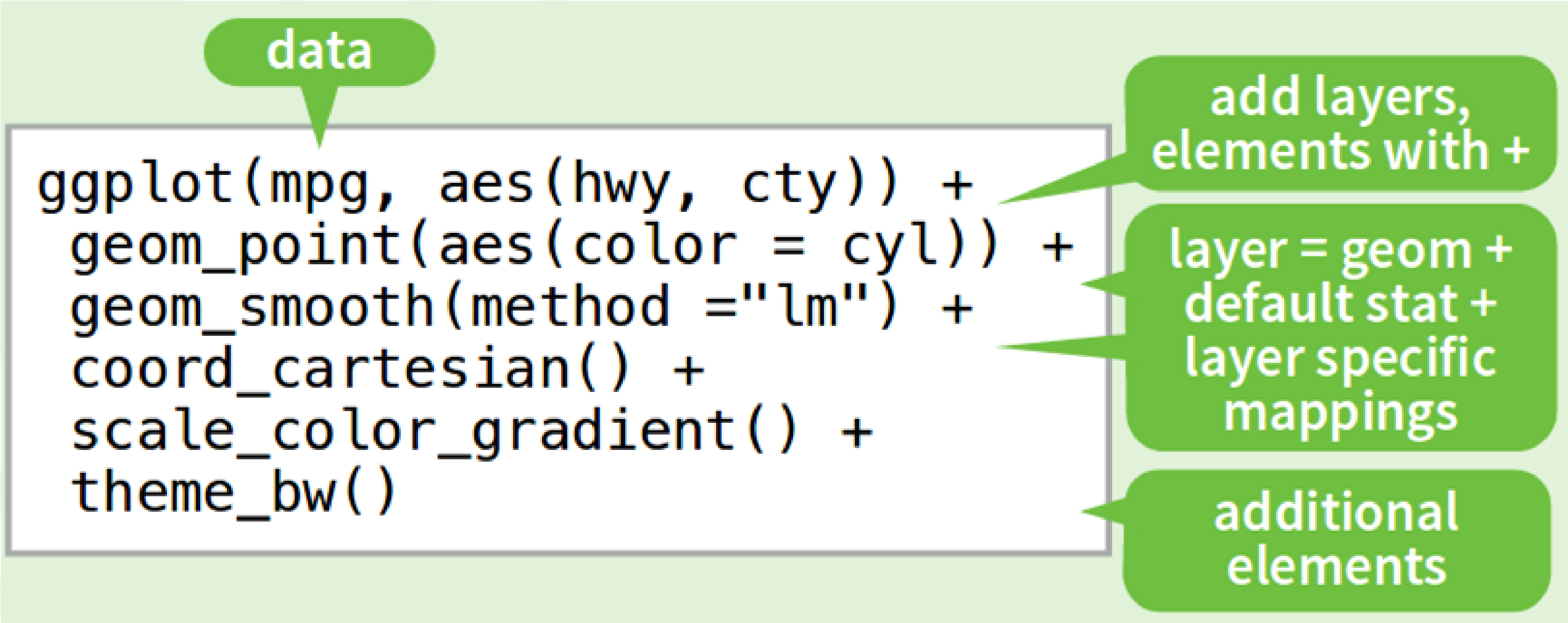
Data Visualization with ggplot2

Basics

ggplot2 is based on the **grammar of graphics**, the idea that you can build every graph from the same components: a **data** set, a **coordinate system**, and **geoms**—visual marks that represent data points.

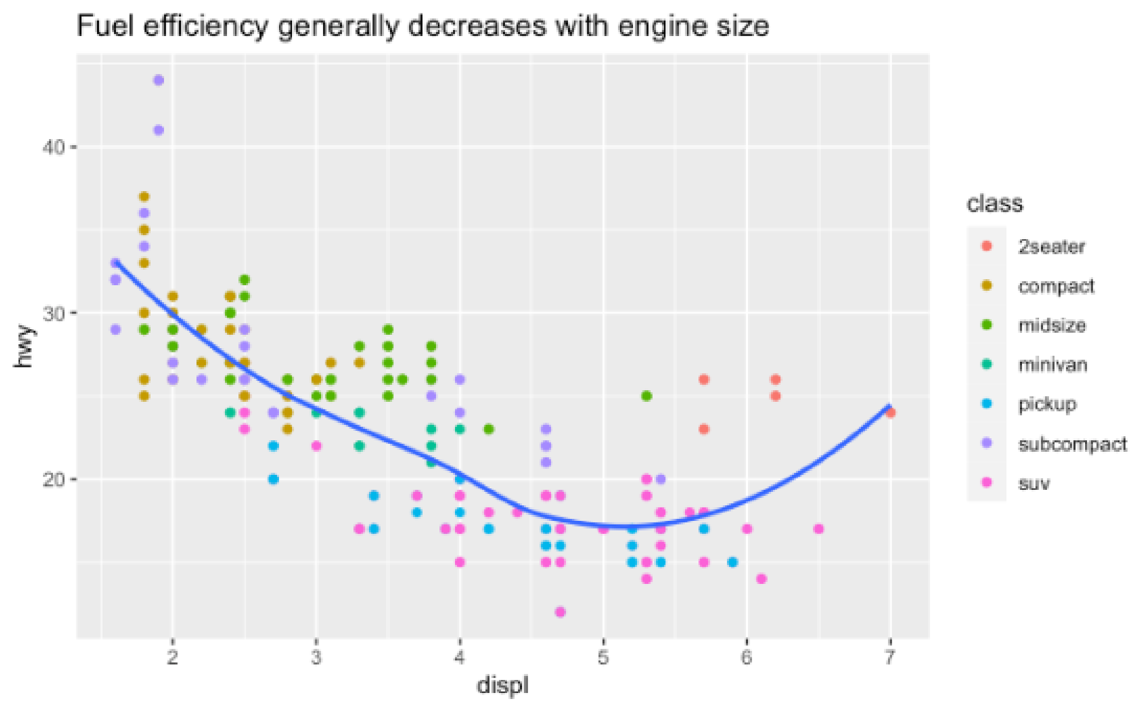
To display values, map variables in the data to visual properties of the geom (**aesthetics**) like **size**, **color**, and **x** and **y** locations.

Data Visualization with ggplot2



Data Visualization with ggplot2

```
ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(color = class)) +
  geom_smooth(se = FALSE) +
  labs(title = "Fuel efficiency generally decreases with engine size")
```



ggplot2: One Dimension

Basic structure

```
ggplot(data=..., aes(x=..., y=...)) +
        geom_...()
```

Exercise

- Make a histogram (geom_histogram()) of cec and pH using dat_3

ggplot2: Two Dimensions

Basic structure

```
ggplot(data=..., aes(x=..., y=...)) +
        geom_...()
```

Exercise

- Make a scatterplot (geom_point()) of cec in x and pH in y using dat_3
- Then, add a fitting line (geom_smooth())

ggplot2: Three Dimensions

Basic structure

```
ggplot(data=..., aes(x=..., y=...)) +
        geom_...()
```

Exercise

- Make a scatterplot (geom_point()) of cec in x and pH in y using dat_3
- Add cec as argument color and size

ggplot2: Three Dimensions

Basic structure

```
ggplot(data=..., aes(x=..., y=...)) +
        geom_...()
```

Exercise

- Make a scatterplot (geom_point()) of cec in x and pH in y using dat_3
- Add cec as argument color and size

ggplot2: Facets

Basic structure

```
ggplot(data=..., aes(x=..., y=...)) +
        geom_...() +
        facet_wrap(~variable)
```

Exercise

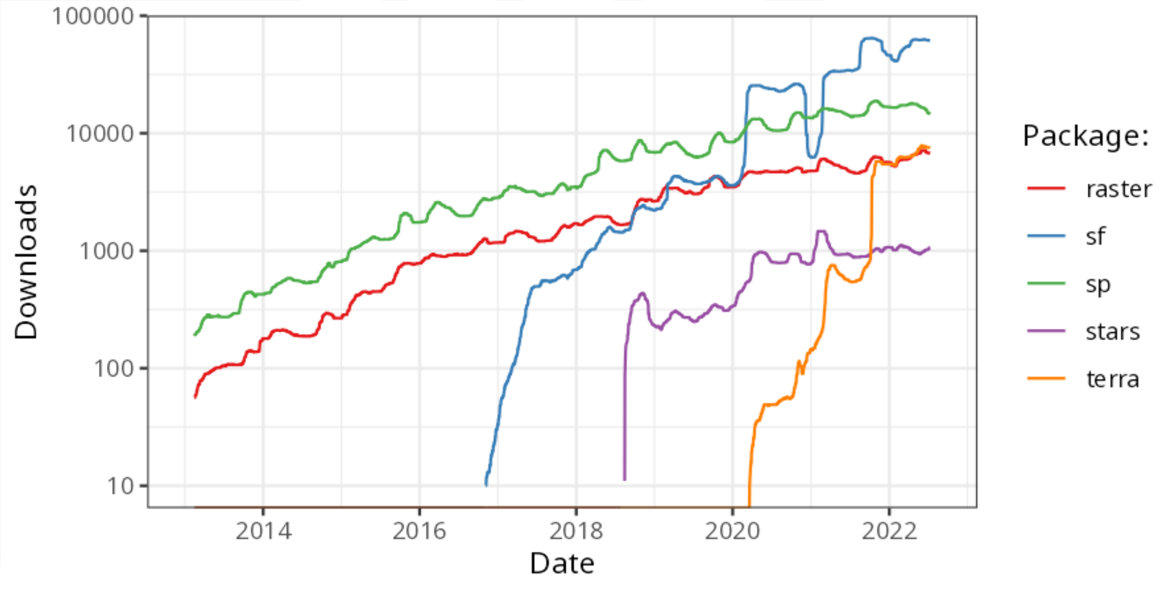
- Make a scatterplot (geom_point()) of cec in x and pH in y using dat_3
- Add cec as argument color and size

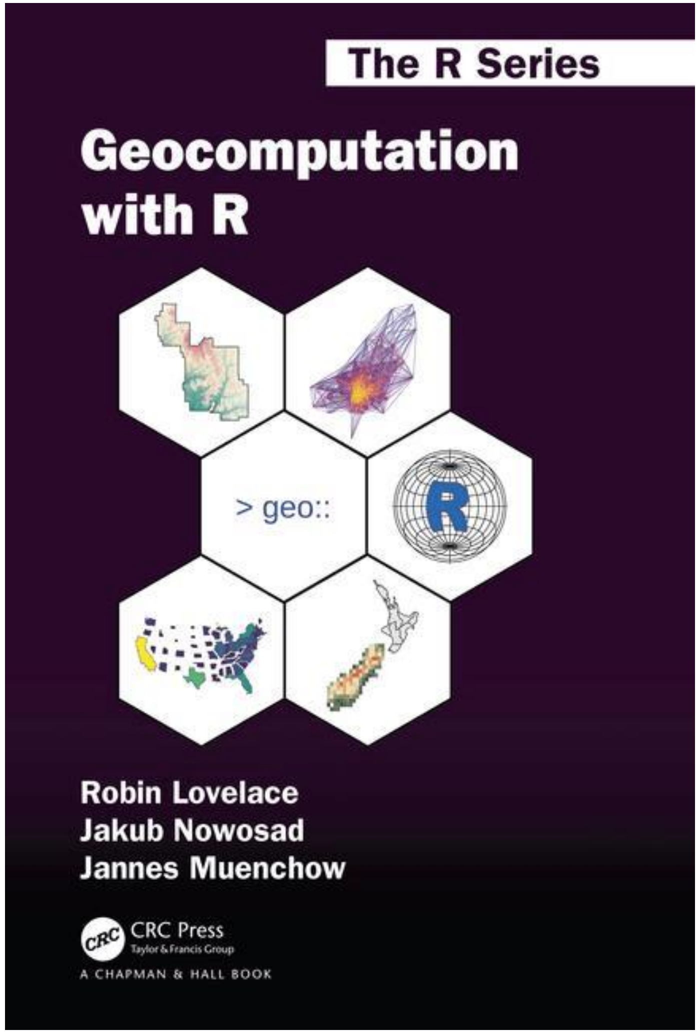
R Basics

Spatial data

Geospatial data in R

https://geocompr.robinlovelace.net/index.html





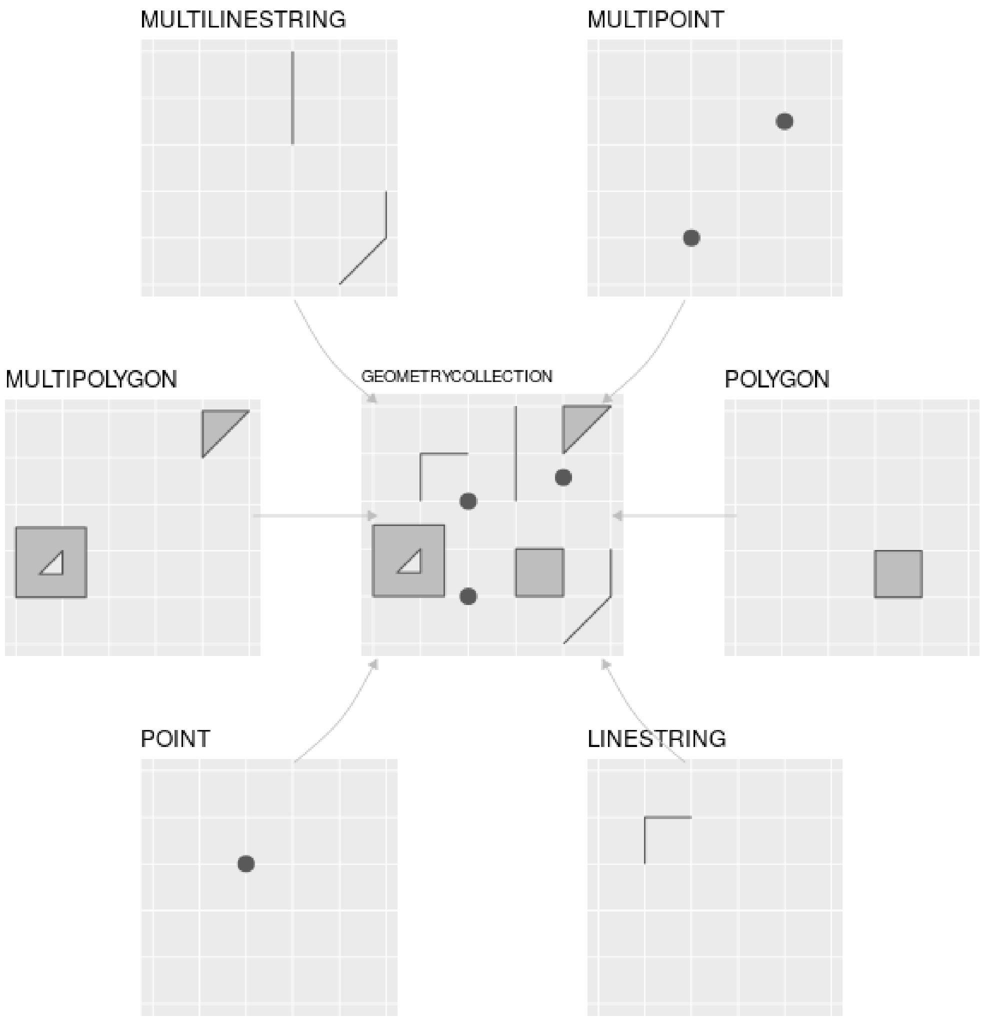
Main concepts

Geospatial data is data with spatial coordinates represented in a coordinate reference system (CRS)

Search the CSR of your country at https://epsg.io/

Vector data

- Vector data represent spatial discrete object, such as regions, roads, rivers, cities, etc.
- Simple features (sf) is an open standard (ISO 19125-1:2004) developed and endorsed by the Open Geospatial Consortium (OGC). The package sf has been developed to manage this type of data
- Attributes are typically stored in data.frame objects. Geometries are also stored in a data.frame column.
- sf objects can be treated as a data.frame



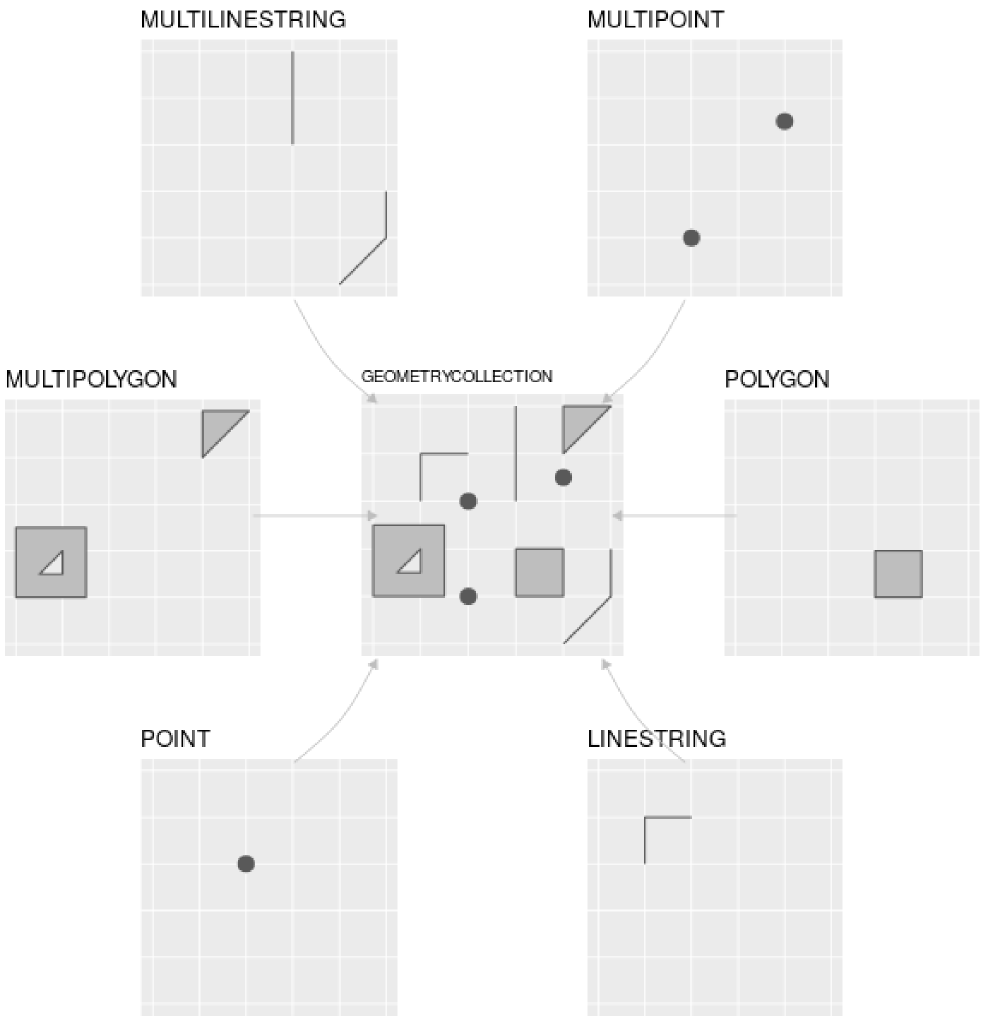
Vector data

```
## Simple feature collection with 100 features and 6 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## epsg (SRID):    4267
## proj4string:    +proj=longlat +datum=NAD27 +no_defs
## precision:      double (default; no precision model)
## First 3 features:
##   BIR74 SID74 NWBIR74 BIR79 SID79 NWBIR79                        geom
## 1  1091     1      10  1364     0      19 MULTIPOLYGON(((-81.47275543...
## 2   487     0      10   542     3      12 MULTIPOLYGON(((-81.23989105...
## 3  3188     5     208  3616     6     260 MULTIPOLYGON(((-80.45634460...
```

Simple feature

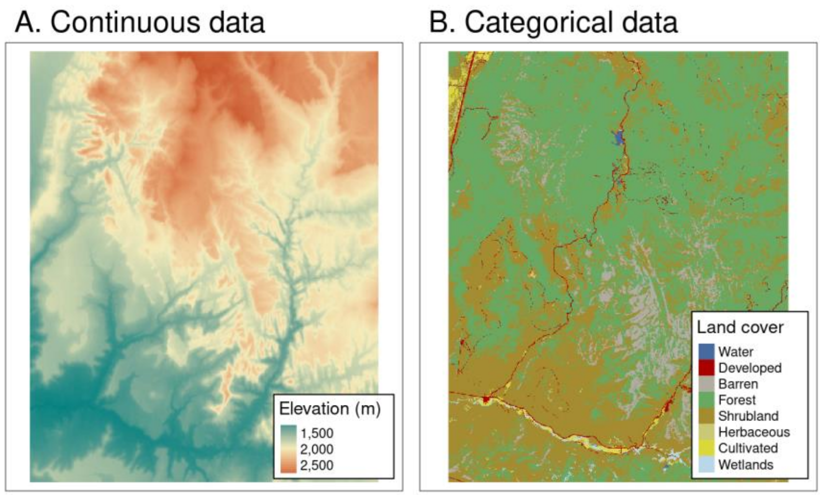
Simple feature geometry list-colum (sfc)

Simple feature geometry (sfg)



Raster data

- The spatial raster data model represents the world with the continuous grid of cells
- It is an appropriate format for continuous variables, such as remote sensing data, terrain attributes, etc., although also categorical data can be represented



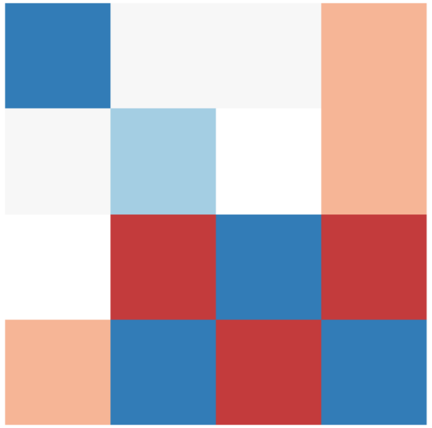
A. Cell IDs

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

B. Cell values

92	55	48	21
58	70	NA	37
NA	12	94	11
36	83	4	88

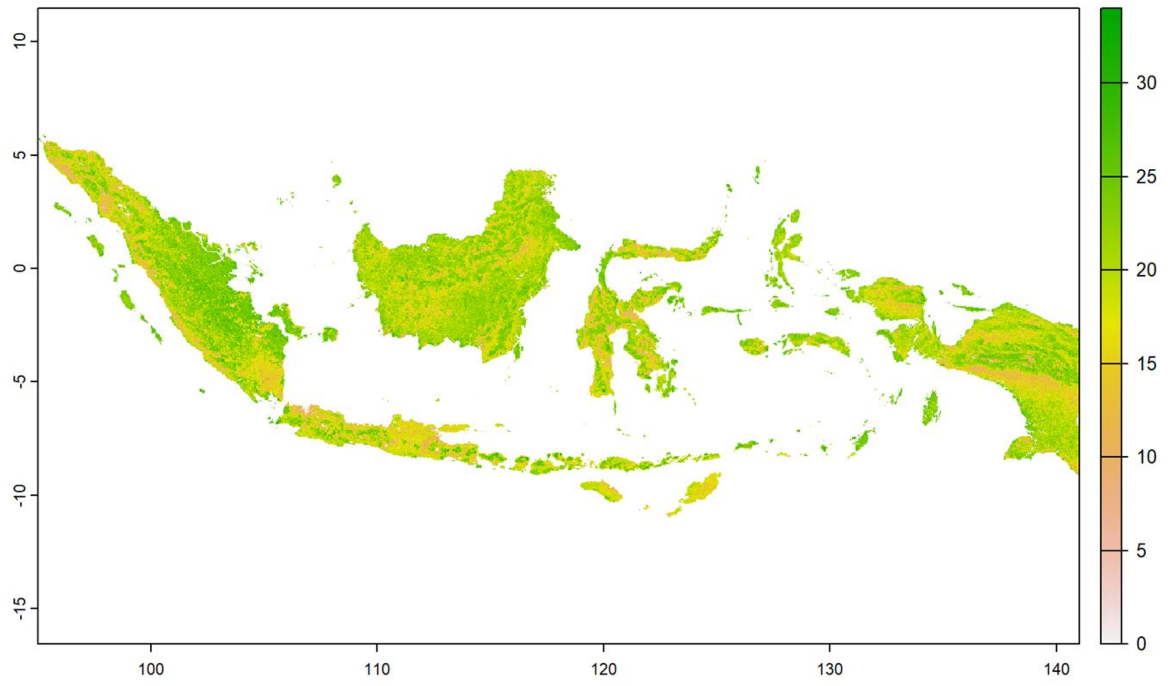
C. Colored values



Raster data

- The main package for handling raster data was called "raster" and has been recently by "terra". However, many packages still use raster as raster data manager
- The main attributes of a raster model are:
    - Number of rows and columns
    - Number of layers
    - Pixel size (or resolution)
    - CRS

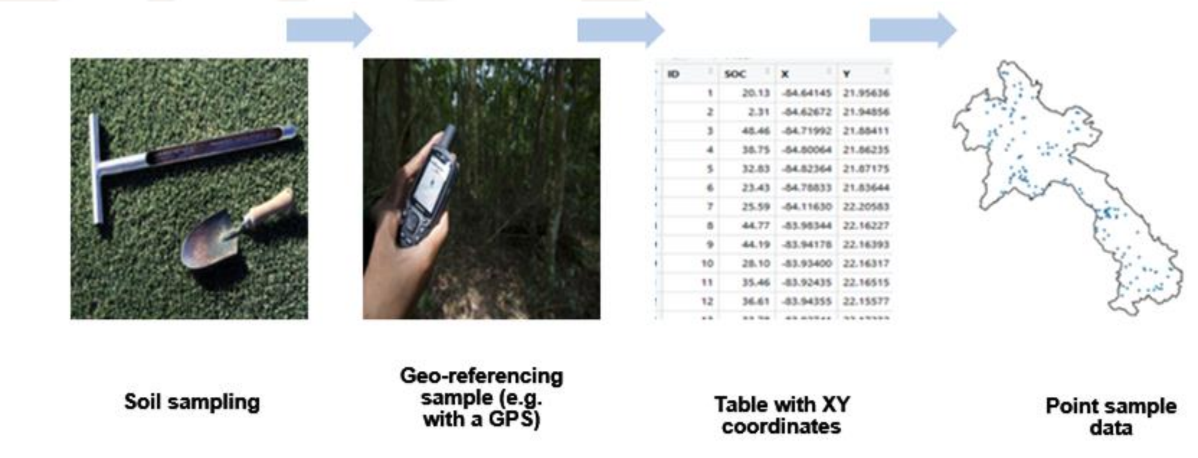
```
#> class       : SpatRaster
#> dimensions  : 457, 465, 1  (nrow, ncol, nlyr)
#> resolution  : 0.000833, 0.000833  (x, y)
#> extent      : -113, -113, 37.1, 37.5  (xmin, xmax, ymin, ymax)
#> coord. ref. : lon/lat WGS 84 (EPSG:4326)
#> source      : srtm.tif
#> name        : srtm
#> min value   : 1024
#> max value   : 2892
```



Raster data

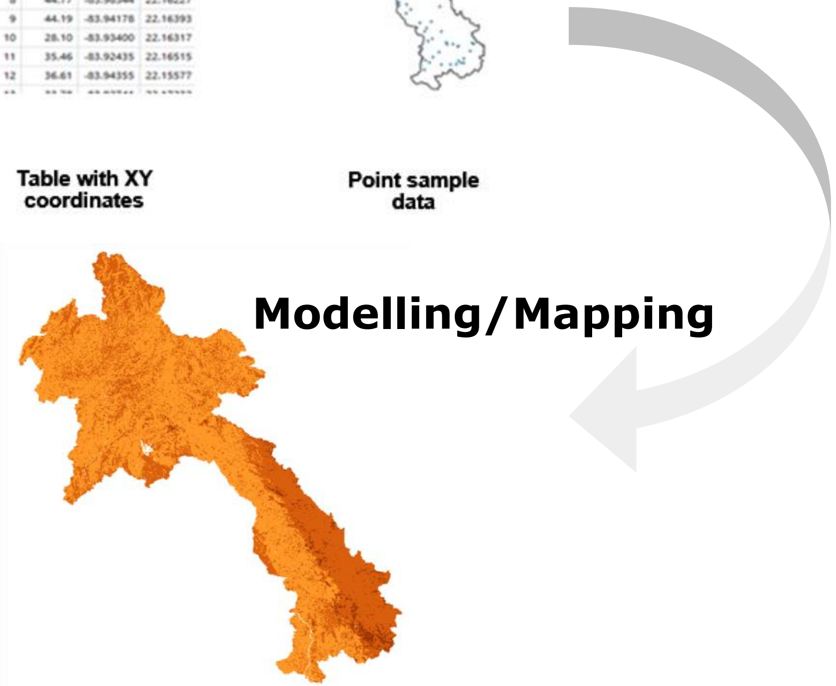
- terra can also handle vector data, which is specially recommended when rasters and vectors need to be combined in any way (convert vector to raster, zonal statistics, etc.)

Digital soil mapping



ID	SOC	X	Y
1	20.13	-84.64145	21.95636
2	2.31	-84.62672	21.94856
3	48.46	-84.71992	21.88411
4	38.75	-84.80064	21.86235
5	32.83	-84.82364	21.87175
6	23.43	-84.78833	21.83644
7	25.59	-84.11630	22.20583
8	44.77	-83.98344	22.16227
9	44.19	-83.94178	22.16393
10	28.10	-83.93400	22.16317
11	35.46	-83.92435	22.16515
12	36.61	-83.94355	22.15577

- In digital soil mapping we mostly work with data in table format and then rasterize this data so that we can make a continuous map



terra package

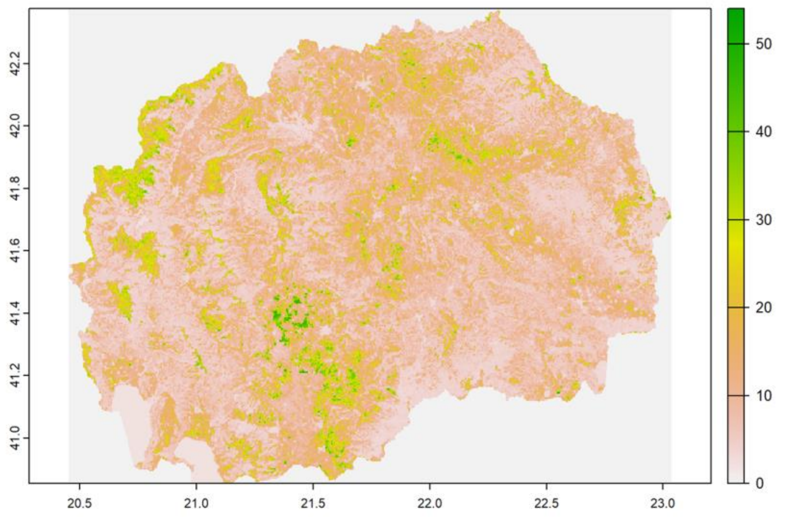
To familiarize with handling spatial data in R, we will focus on:

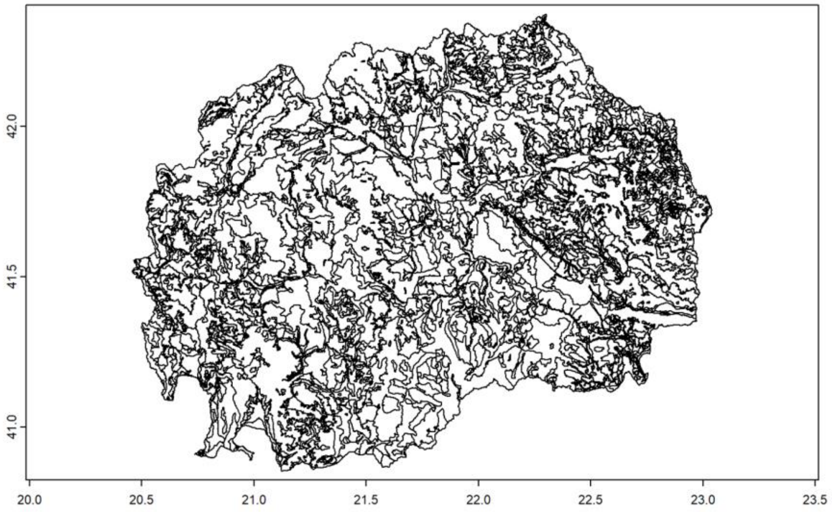
- Load a raster with `rast()` and explore its attributes
- Load a vector with `vect()` and explore its attributes
- Transform their coordinate system (`project()`)
- Cropping (`crop()`) and masking (`mask()`) a raster
- Replace values in a raster by filtering their cells
- Rasterize (`rasterize()`) a vector layer
- Extracting raster values (`extract()`) using points
- Zonal statistics (`zonal()`) using polygons and rasters

terra: rast() & vect()

Exercise

- Load 01-Data/covs/grass.tif using rast() function, then plot it
- Load 01-Data/soil map/SoilTypes.shp using vect() function and plot it
- Explore the attributes of these layers

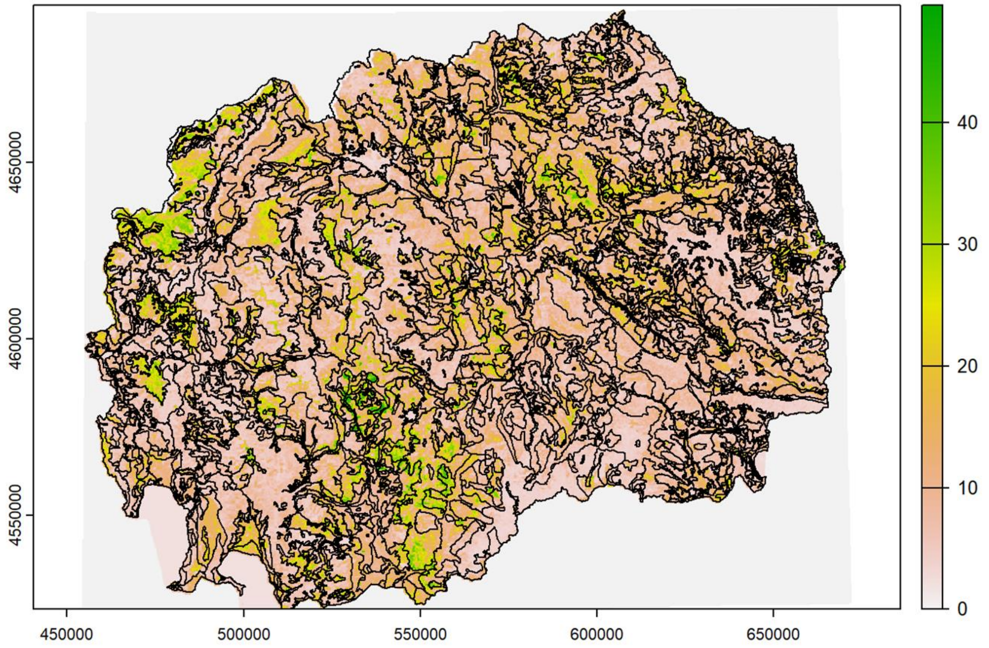




terra: project()

Exercise

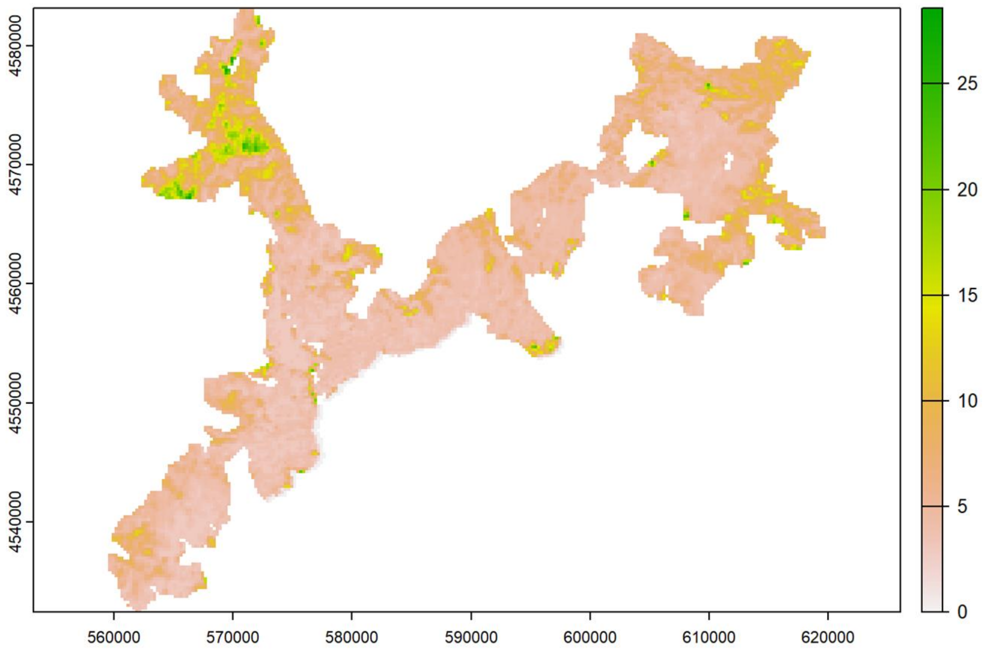
- Check the current CRS (EPSG) of the raster and the vector.
- Find a *projected* CRS in http://epsg.io for Macedonia and copy the number
- Check the Arguments of function project (?project) that need to be defined
- Save the new object as r_proj and v_proj
- plot both objects (used add=TRUE in plot function)



terra: crop() and mask()

Exercise

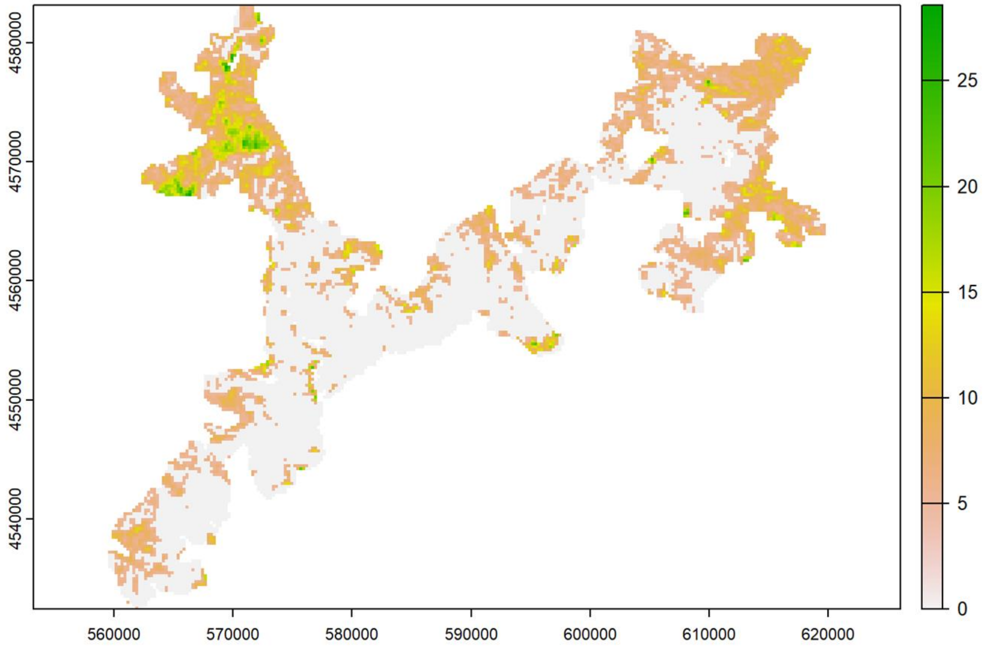
- Compute the area of the polygons in v_proj (search for a function) and
- assign the values to a new column named area
- select the largest polygon using [], $, == and max() func. and save it as pol
    - Use it as it were a dataframe, for example df[df$col == max(df$col)]
- crop the raster with pol using the crop() function and save it as r_pol
- mask the raster r_pol with the polygon pol and save it with the same name
- Plot each result



terra: replace cell values

Exercise

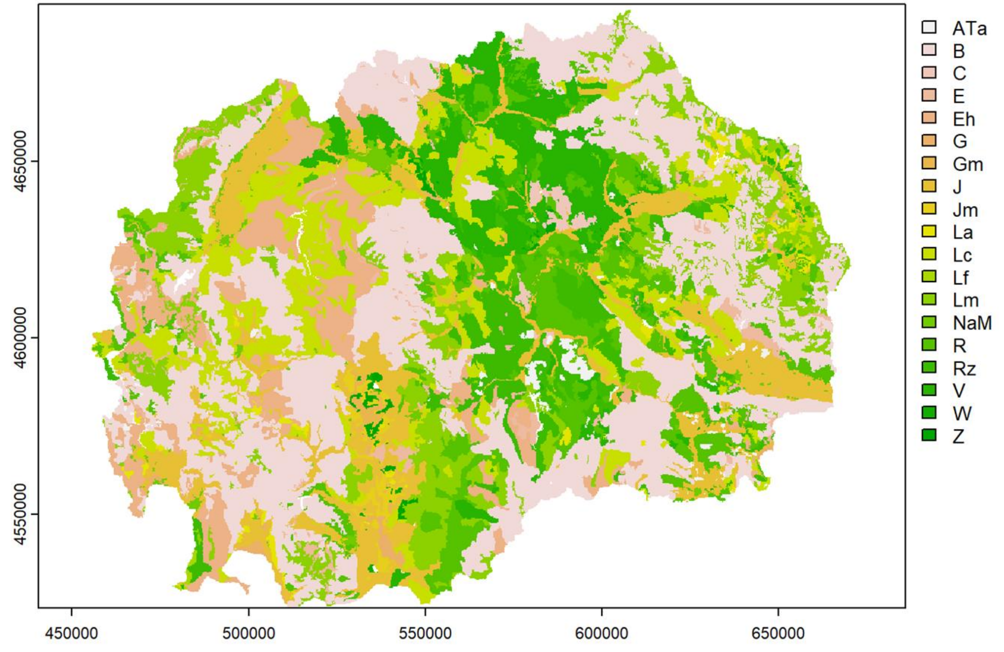
- Explore the following link to understand how terra manage cell values
- https://rspatial.org/terra/pkg/4-algebra.html
- Replace values lower than 5 in r+pol by 0



terra: rasterize()

Exercise

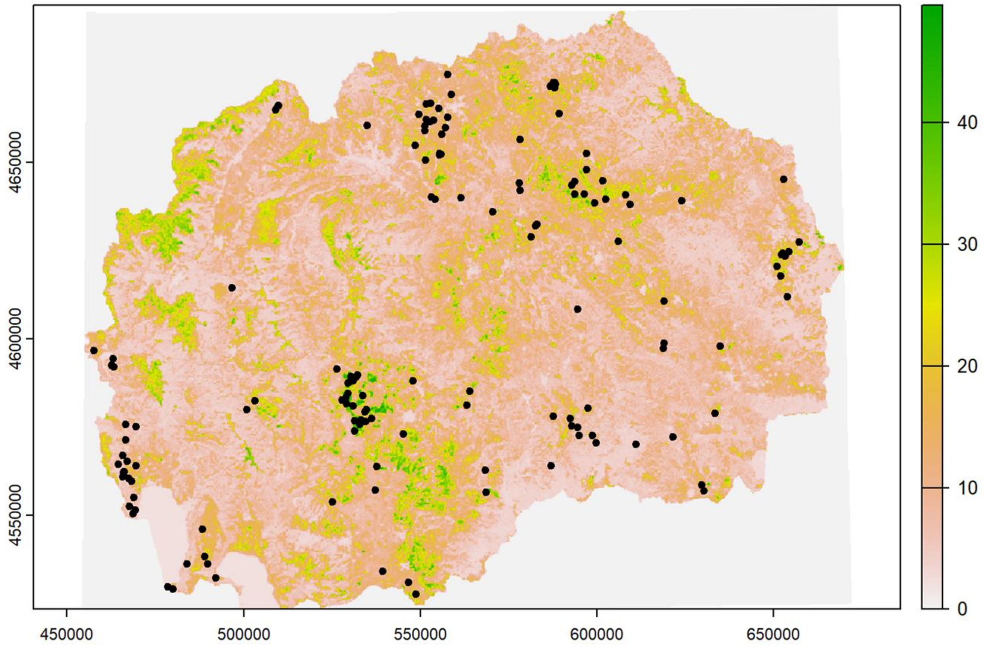
- Use rasterize() function to convert v_proj to raster
- Use r_proj as reference raster
- Use field Symbol to assign cell values, and plot the new map



terra: extract()

Exercise

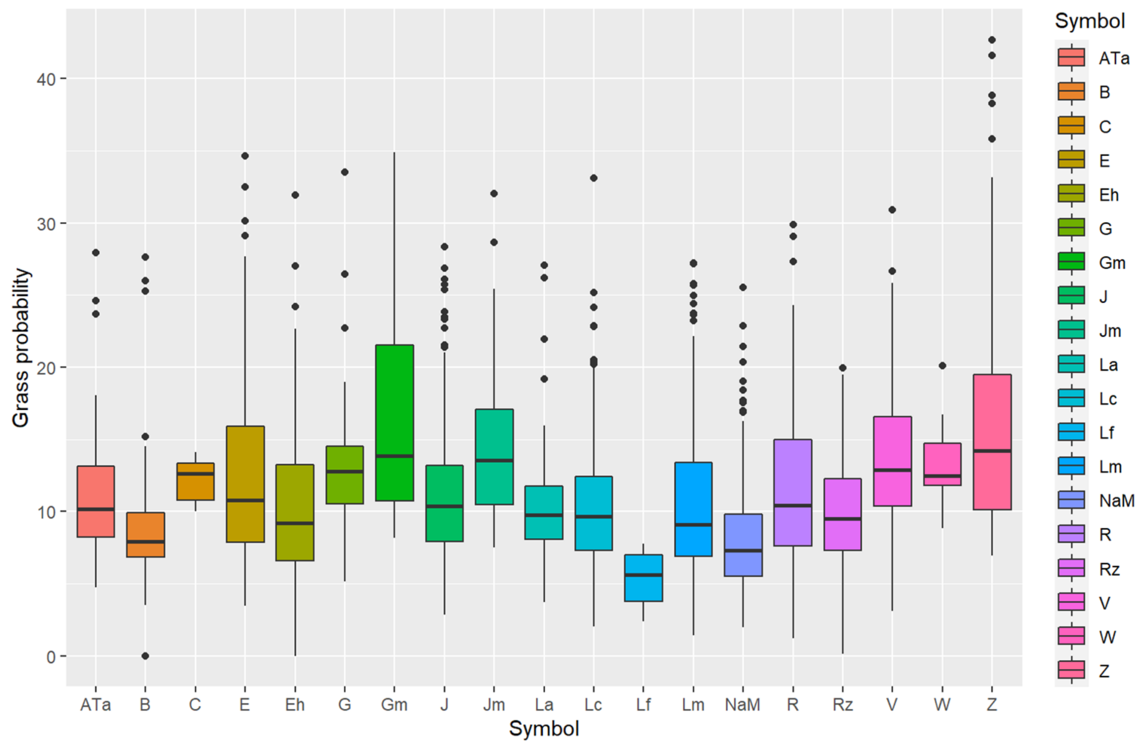
- Convert dat_6 to spatial points using vect() function (check help of vect())
- Note that the EPSG number is 6204
- Save the points as s
- Plot s and r_proj together in the same map (Argument add=TRUE)
- Extract the values of the raster using extract() function (check the help)
- Remove the ID column of the extracted values
- Merge the extracted data with s using cbind() function
- Convert s as a dataframe



terra: zonal statistics

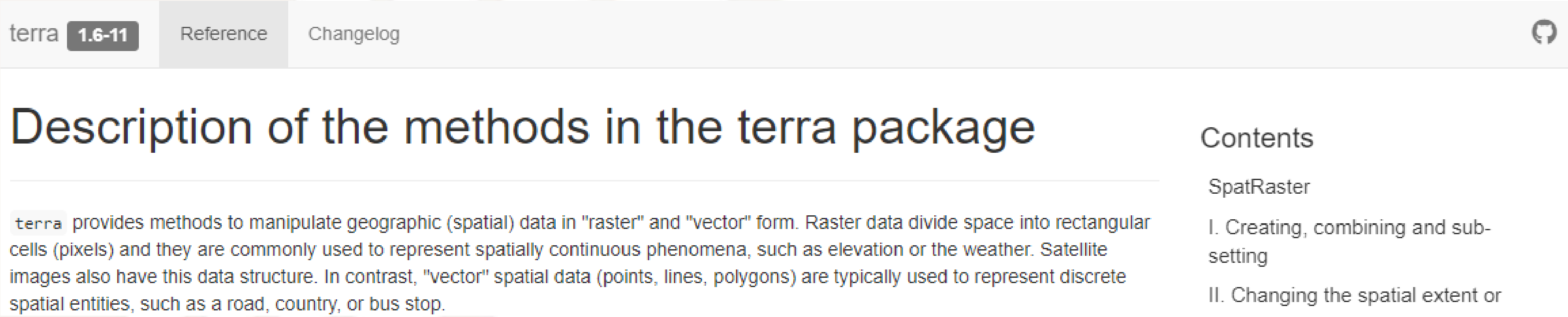
Exercise

- Use the extract() func. to estimate the mean value of r_proj at each polygon
- Use the fun= argument (check the help)
- Use the cbind() func. to merge v_proj and the extracted values
- Convert v_proj to a dataframe
- Create a ggplot boxplot (geom_boxplot) with x=Symbol and y=grass

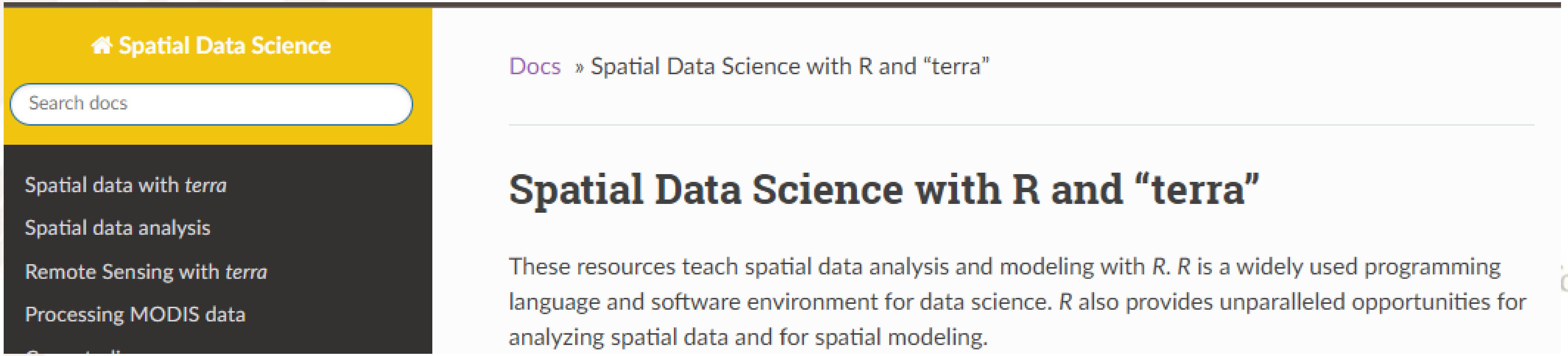


terra package

https://rspatial.github.io/terra/reference/terra-package.html



https://rspatial.org/terra/index.html



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