GIS in R: Fundamentals and Economic Applications

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Welcome!

This book was created in order to host all of the materials for AREC 493 class.

Spatial data is increasingly essential for understanding economic activity, policy and development. This course introduces students to the use of R as a Geographic Information System (GIS) for economic analysis. Students will learn core GIS concepts alongside the basics of R programming, with a focus on practical applications in economics. The course closely integrates *tidyverse* functions with GIS tools to develop efficient and intuitive coding. Topics include spatial data processing, covering the import, management, and manipulation of raster and vector data, as well as visualization of spatial data through maps to identify spatial patterns. By the end, students will have the skills to integrate spatial analysis into economic research, enabling them to work with powerful and flexible tools for investigating real-world economic questions.

Be aware that the book is currently being written and will be completed by the end of the semester. Let me know if you think any changes are necessary!

1 Syllabus

1.1 Course Information

Course: AREC 493

Instructor: Dr. Gaby Perez-Quesada

Email: gperezqu@utk.edu

Term: Spring 2026

Times: T & R, 2:30-3:45pm

Location: Morgan Hall 212B

Office Hours: T & R, 3:45-5:00pm

1.2 Learning Objectives

- Use R and ***tidyverse*** tools to import, clean, and manipulate spatial data efficiently and reproducibly
- Explain and apply core GIS concepts, including spatial data types, projections, and coordinate reference systems
- Work with vector and raster datasets, performing basic operations, analysis, and integration between data types
- Visualize spatial data effectively through maps to identify and interpret spatial patterns
- Access and process real-world spatial datasets from public sources for applied economic analysis

1.3 Prerequisites

AREC 270. Prior coursework in basic statistics or econometrics is recommended. Students should be comfortable with fundamental concepts such as descriptive statistics, regression analysis, and interpreting empirical results.

1.4 Lecture Topics

(*Subject to change based on progression through the material*)

Getting started with R

- Get started with running code
- Install and load libraries
- Load in data from files, the internet, or libraries
- Write good code and responsibly use AI in your coding
- Look at your data and get basic statistical results
- Manipulate your data and get it ready for analysis

GIS fundamentals

- Types of spatial data
- Projections and coordinate reference system

The basics of vector data handling using *sf* package

- Vector data (points, lines, polygons)
- Import and export vector data
- (re)projection of spatial datasets
- Single-layer geometrical operations (e.g., create buffers)

Spatial interactions of vector datasets

- Understand topological relations of multiple *sf* objects
- Spatially subset a layer based on another layer
- Extracting values form one layer to another layer

The basics of raster data handling using *raster* and *terra* packages

- Import and export raster data
- Stack raster data
- Quick plotting

Spatial interactions of vector and raster datasets

- Cropping a raster layer to the geographic extent of a vector layer
- Extracting values form a raster to a vector later

Creating maps using *ggplot2* package

- Visualizing spatial data with ggplot2

Download and process publicly available datasets

- USDA NASS QuickStat (*tidyUSDA*)
- PRISM (*prism*)
- Daymet (*daymetr*)
- Cropland Data Layer (*CropScapeR*)
- Census (*tidycensus*)

1.5 Course Materials

This course will follow a set of high-quality, freely available online resources, alongside DataCamp Classroom. Students are encouraged to consult these materials to complement lectures and exercises.

Introduction to R

- R for Data Science
- Introduction to Working with Data: R version

R for GIS

- R as GIS for Economists
- Spatial Statistics for Data Science: Theory and Practice with R

1.6 Grading

Assignments: 30%

Midterm Exam: 25%

Participation: 15%

Final Project: 30%

1.7 Academic Integrity

In accordance with the college's academic honesty policy, students are expected to submit original work for all assignments. Any form of academic dishonesty will not be tolerated. Plagiarism includes copying answers, phrases, sentence structures, or ideas from any source without proper attribution.

This also applies to the use of artificial intelligence tools such as ChatGPT. While you may use AI to assist with coding or to explore solutions, you must not simply feed it questions and submit the generated responses as your own work. All submitted assignments should reflect your understanding and effort.

1.8 Generative AI Tools in Coursework

Open Use Guidelines: Embrace and encourage AI use in assignments, with the requirement that students disclose any AI assistance.

AI policy: permitted in this course with attribution

In this course, students are allowed to use Generative AI Tools like ChatGPT to support their work. To maintain academic integrity, students must disclose any AI-generated material they use and properly attribute it, including in-text citations, quotations, and references.

A student should include the following statement in assignments to indicate use of a Generative AI Tool: "The author(s) would like to acknowledge the use of [Generative AI Tool Name], a language model developed by [Generative AI Tool Provider], in the preparation of this assignment. The [Generative AI Tool Name] was used in the following way(s) in this assignment [e.g., coding, brainstorming, grammatical correction, citation, which portion of the assignment]."

1.9 Accommodations for Students with Disabilities

I am available to discuss appropriate academic accommodations that may be required for student with disabilities. The University of Tennessee, Knoxville, is committed to providing an inclusive learning environment for all students. If you anticipate or experience a barrier in this course due to a chronic health condition, a learning, hearing, neurological, mental health, vision, physical, or other kind of disability, or a temporary injury, you are encouraged to contact Student Disability Services (SDS) at 865-974-6087 or sds@utk.edu. An SDS Coordinator will meet with you to develop a plan to ensure you have equitable access to this course. If you are already registered with SDS, please contact your instructor to discuss implementing accommodations included in your course access letter.

1.10 Online@UT

Students are required to routinely access their UTK email account and the course website located on the Online@UT (Canvas) portal

2 Getting Started with R

2.1 Why use R?

As stated on the R Project website, R is a programming language and environment for statistical computing and graphics. It's flexible, easy to build on, and supported by a large, welcoming community.

Cost

R is free and open-source for everyone.

Reproducibility

Using a programming language for data management and analysis, rather than relying on Excel or other point-and-click tools, makes your work easier to reproduce, helps you catch mistakes more quickly, and can save you a lot of time and effort.

Community

The R community is huge and supportive. New packages and tools to tackle real-world problems are developed all the time, and the community helps test, improve, and share them.

2.2 Installation: R and RStudio

To get started, you'll need to have R running on your computer. There are a few options, but **RStudio** is a popular choice that makes working with R much easier.

Installing RStudio takes two steps. First, you'll need to install the R language itself.

How to install R

Visit this website https://www.r-project.org and download the latest version of R suitable for your computer. *Note*: Any mirror will work fine, but perhaps pick one close to you.

Once that's done, you can **install RStudio**

Go to this website https://posit.co/download/rstudio-desktop/ and download the latest free Desktop version of RStudio suitable for your computer.

2.3 Navigating RStudio

Open RStudio. RStudio is divided into four main *panes*, each showing different information like your code, console, and files.

The source pane

By default, this pane appears in the upper-left corner. It's where you can write, run, and save your scripts (your scripts are basically the sets of commands you want R to execute. You can also use this pane to view your datasets (data frames) while working.

The R console pane

The R Console (usually in the lower-left pane) is where the R "engine" lives. When you run commands here, you'll see results, warnings, or error messages right away. You can type commands directly in the Console, but unlike scripts, these commands won't be saved for later, so it's best for quick tests or checks.

The environment pane

By default, this pane appears in the upper-right. It's mainly used to get a quick look at the objects in your R environment during the current session. These objects can include datasets you've imported, created, or modified, as well as parameters or vectors and lists you've defined. You can click the little arrow next to a data frame to explore its variables.

Plots, Viewer, Packages, and Help pane

The lower-right pane contains several useful tabs. The *Plots* tab displays your charts, graphs, and maps, while the *Viewer* tab shows interactive or HTML outputs. The *Help* tab gives access to R documentation and help files, and the *Files* tab works like a mini file explorer, letting you open, move, or delete files. Finally, the *Packages* tab lets you see which R packages are installed, add new ones, update or remove them, and load or unload them for your session.

2.4 Scripts

Scripts are a fundamental part of programming. They're files that store the commands you want R to run, like creating or modifying datasets and generating visualizations. You can save a script and run it again later, which comes with some big advantages:

Portability: you can easily share your work with others by sending them your script.

Reproducibility: using scripts makes it clear exactly what steps you took, so you, or anyone else, can repeat your analysis with confidence.

Example script

```r
3 + 4
```

```
[1] 7
```

```r
a <- 3 + 4 # you can annotate around your code!
```

2.5 Quarto

Quarto is a tool that lets you combine your R code, text, and visualizations in a single document. It's perfect for creating reports, tutorials, or assignments where you want your analysis and explanations to live side by side. With Quarto, you can run your code, include the results, and produce a polished document; all in one place, making your work easy to share and easy to reproduce.

We will use Quarto document (.qmd) to write and edit your code!

Free online resources:

Tutorial: Hello Quarto

R for Data Science: Quarto

2.6 Working directory

The working directory (wd) is the root folder location used by R for your work, where R looks for and save files by default. R will save new files and outputs to this location, and will look for files to import (e.g. datasets) here as well.

The `wd` information appears at the top pf the Console pane. You can also print the current `wd` by running `getwd()` function.


```r
getwd()
```

```
[1] "/Users/gperezqu/Library/CloudStorage/OneDrive-UniversityofTennessee/University of Tenne
```

A recommended (and very efficient) approach is to use R projects. When you work inside the R project, your `wd` is automatically set to the project's root folder, which contains the `.rproj` file. This happens whenever you open RStudio by double-clicking the ".rproj" file, so you don't need to set the working directory yourself.

2.7 Create your R project

1. Create a folder in your computer (e.g., Project1)
2. Open RStudio
3. Click File → New Project
4. Click Browse
5. Select the folder you created (`Project1`)
6. Click Create Project

RStudio will now:

- Open the project
- Create a `.rproj` in the folder
- Set the `wd` automatically

7. Confirm you're in the project

You should see:

- the project name in the top-right corner of RStudio
- a file ending in `.rproj` in the Files pane

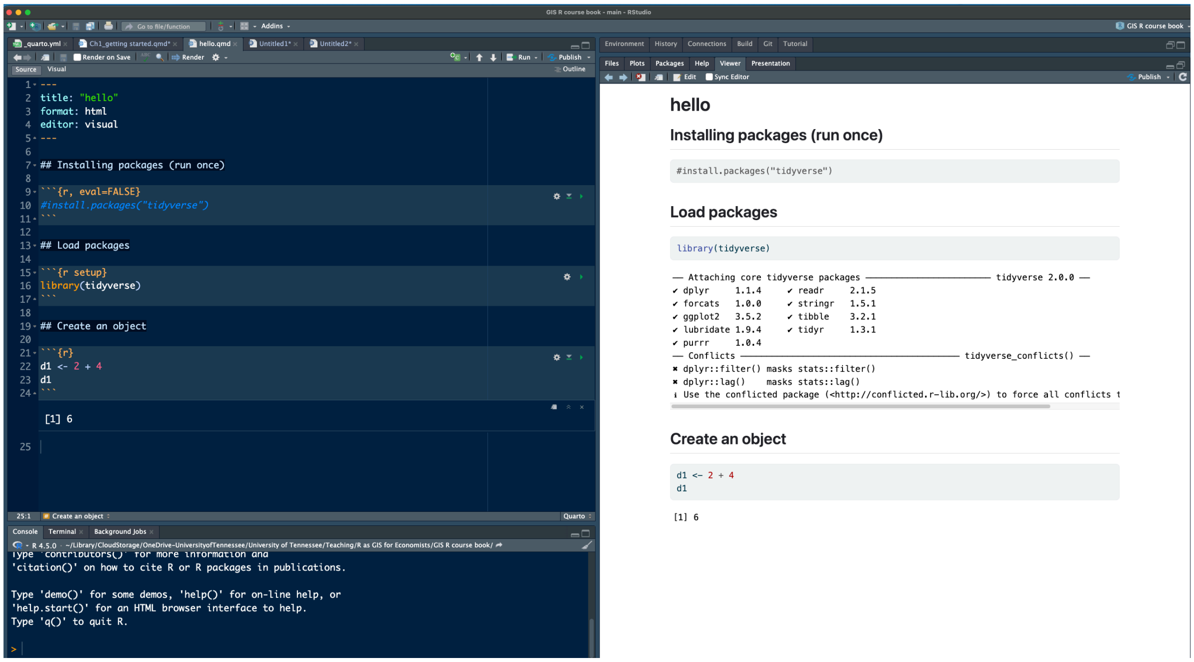
8. Create your first `Quarto` document

- Click File → New File → Quarto Document…
- Choose: Format: HTML; Engine: Knitr
- Click Create
- Save as → `hello`

Always open your project **by double-clicking** the `.rproj` file, not by opening RStudio first and setting the `wd` manually.

2.8 Quarto file (`.qmd`) overview

Below is a Quarto document (the `.qmd` file on the left) and its rendered output as an HTML page (on the right). The `.qmd` file is where you write your content and code, and when you render it, Quarto turns it into a polished document. You're not limited to HTML, you can also render the same file as a PDF, a Word document, and more.



- Select `Preview in Viewer Pane` if you want to see the rendered output on the `Viewer Pane`.
- Click on the `Render` button to render the file and preview the output.
- Two modes of the RStudio editor: `visual` (on the left) and `source` (on the right). `visual`: what-you-see-is-what-you-mean (WYSIWYM) experience, so you can format text without worrying about markdown syntax. `source`: plain-text markdown code.

3 hello Quarto

3.1 Headings

In this paper….

3.1.1 subsection

Some more text… This is **bold** text

My name is **Gaby…**

Use `#` symbols for section titles. Leave a blank line after headings for readability.

Section title

Subsection title

Smaller heading (more # = smaller heading)

3.2 Bold and italic text

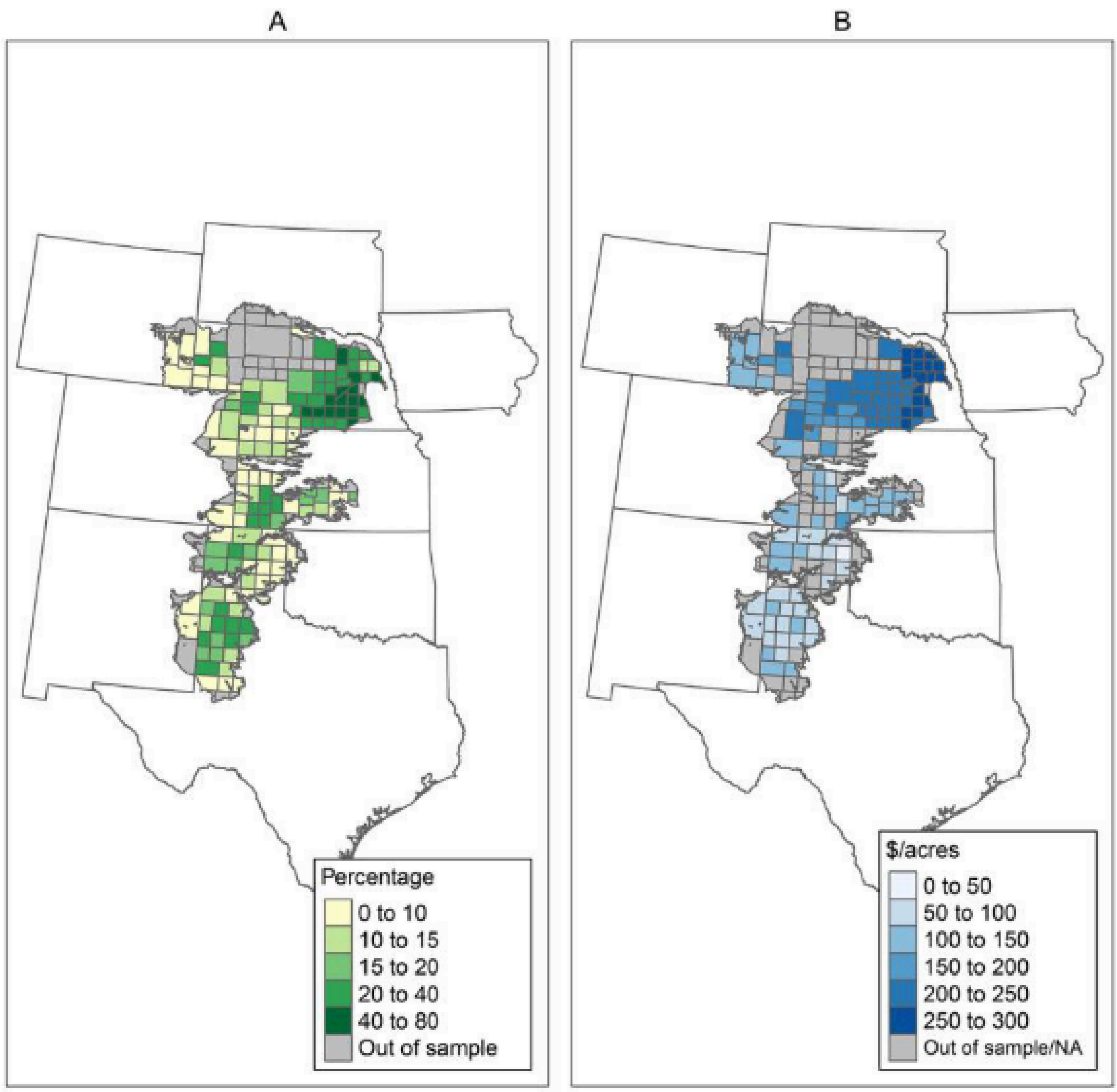
If you are using `Source`: **text** and *italic*

If you are using `Visual`: Click Format → Bold

3.3 Adding figures and links

Find any image and save it as `.png` in your R project.

The figure below shows that…



You can learn more about this paper here.

How to include figures and links when using `Visual`?

3.4 Code chuncks

R code chunks are marked with `{r}`. Type the chunk by hand or using keyboard shortcut.

Mac: Command + Option + I

Windows: Ctrl + Alt + I

```
# your R code goes here
# comment
```

3.5 Common chunck options

- eval = FALSE → show code, don't run it
- echo = FALSE → run code, don't show it
- include = FALSE → run code, show nothing
- message = FALSE → hide package messages
- warning = FALSE → hide warnings

Example:

```
d1 <- 4 + 8
d1
```

```
[1] 12
```

```
[1] 12
```

3.6 Installing packages (run once) and loading library

```
#install.packages("tidyverse")
library(tidyverse) # Load packages
```

```
-- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
v dplyr     1.1.4     v readr     2.1.5
v forcats   1.0.0     v stringr   1.5.1
v ggplot2   3.5.2     v tibble    3.2.1
v lubridate 1.9.4     v tidyr     1.3.1
v purrr     1.0.4
-- Conflicts ------------------------------------------ tidyverse_conflicts() --
x dplyr::filter() masks stats::filter()
x dplyr::lag()    masks stats::lag()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to becom
```

3.7 Create an object

Everything in R is an object, and R is an object-oriented language. An object exists once you assign a value to it.

After an object is created, it appears in the Environment pane. From there, you can use the object in your code (inspect it, manipulate it, change it, or redefine it by assigning it a new value).

```
# Defining an object (<-)
d1 <- 2 + 4
d1
```

```
[1] 6
```

3.8 Using built-in datasets in R

```
#data() # list of datasets
data(mtcars) # load mtcars

# create an object
my.data <- mtcars

# Inspect it
head(my.data)
```

```
                   mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

4 R Basics

4.1 Create an object

Everything in R is an object, and R is an object-oriented language. An object exists once you assign a value to it.

After an object is created, it appears in the Environment pane. From there, you can use the object in your code (inspect it, manipulate it, change it, or redefine it by assigning it a new value).

```r
library(tidyverse)
```

```
-- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
v dplyr     1.1.4     v readr     2.1.5
v forcats   1.0.0     v stringr   1.5.1
v ggplot2   3.5.2     v tibble    3.2.1
v lubridate 1.9.4     v tidyr     1.3.1
v purrr     1.0.4
-- Conflicts ------------------------------------------ tidyverse_conflicts() --
x dplyr::filter() masks stats::filter()
x dplyr::lag()    masks stats::lag()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to becom
```

```r
# Defining an object (<-)
d1 <- 2 + 4
d1
```

```
[1] 6
```

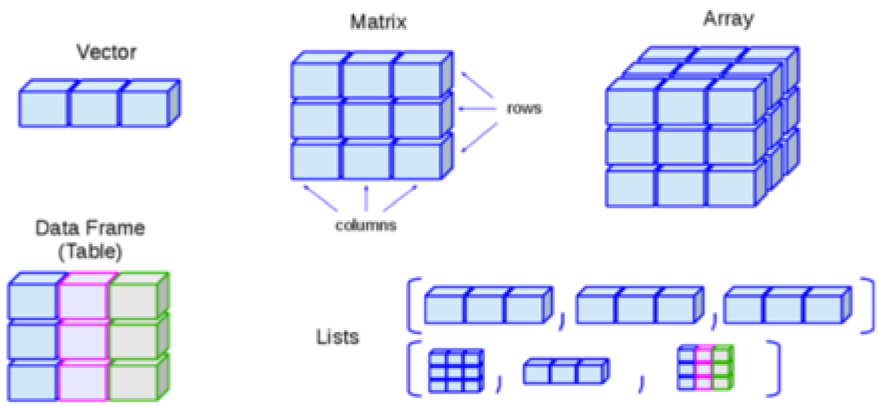
```r
#data()
# Using built-in datasets in R
data(mtcars) # load mtcars

# create an object
```

```
my.data <- mtcars
# Inspect it
head(my.data)
```

```
                   mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

4.2 Object structure

Objects can be as simple as a single value (e.g., `d1`), or they can hold more structured data, such as vectors, tables, or datasets, like the examples shown in the figure below (borrowed from this online R tutorial).



4.2.1 Data types

In this course, we will be using mostly vector and data frame.

Vector: a collection of values of the same type (e.g., numbers or text) stored together in one object.

```
# Numeric vector
numbers <- c(1, 2, 3, 4, 5)
numbers
```

```
[1] 1 2 3 4 5
```

```
class(numbers)
```

```
[1] "numeric"
```

```
# Character vector
names <- c("Alice", "Bob", "Charlie")
class(names)
```

```
[1] "character"
```

data.frame: a table of data where each column is a vector, and all columns have the same number of rows.

```
data(mtcars) # load mtcars

# create an object
my.data <- mtcars
class(my.data)
```

```
[1] "data.frame"
```

4.2.2 Variables types

Variable	Description	Example
integer	Whole numbers	5, 160, -30
numeric	Decimals	0.5, -0.38, 234.567
character	Text	"A", "Nice", "welcome"
logical	Booleans	TRUE or FALSE
factor	Categorical	"green", "blue", "red"
empty	–	NULL

Examples

```
class(d1)
```

```
[1] "numeric"
```

```r
# Numeric (decimal)
num <- 3.14
num2 <- 56 # R treats all numbers without a decimal as numeric by default

class(num)
```

```
[1] "numeric"
```

```r
class(num2)
```

```
[1] "numeric"
```

```r
# Integer
int <- as.integer(num)
class(int)
```

```
[1] "integer"
```

```r
int <- 56L # L tells R to store this as an integer
class(int)
```

```
[1] "integer"
```

```r
x <- 89
x <- 289

# Character (text)
char_var <- "welcome"

# Logical (TRUE/FALSE)
log_var <- TRUE

# Factor (categorical)
fact_var <- factor(c("green", "blue", "red"))

# variables type in my.data
class(my.data$hp)
```

```
[1] "numeric"
```

```r
class(my.data$mpg)
```

```
[1] "numeric"
```

4.3 Functions

Functions are at the core of using R. Want to calculate, plot, or transform something? There's probably a function for it. R comes with lots built in, you can add more with packages, and you can even make your own! Learn more here.

A function is like a little machine: you give it some inputs, it does something with them, and then it gives you an output. What comes out depends on the function you're using.

Inputs → [function] → Output

Simple functions

```r
# Function: sum()
# Inputs: numbers
# Action: adds them together
# Output: the total
sum(4, 7, 10)
```

```
[1] 21
```

```r
result <- sum(4, 7, 10)
result
```

```
[1] 21
```

```r
# Function: as.numeric()
# Inputs: char_nums
# Action: convert to numeric
# Output: num_nums

# Convert a character vector to numeric
char_nums <- c("1", "2", "3", "4")
class(char_nums)
```

```
[1] "character"
```

```r
# Convert to numeric
num_nums <- as.numeric(char_nums)
class(num_nums)
```

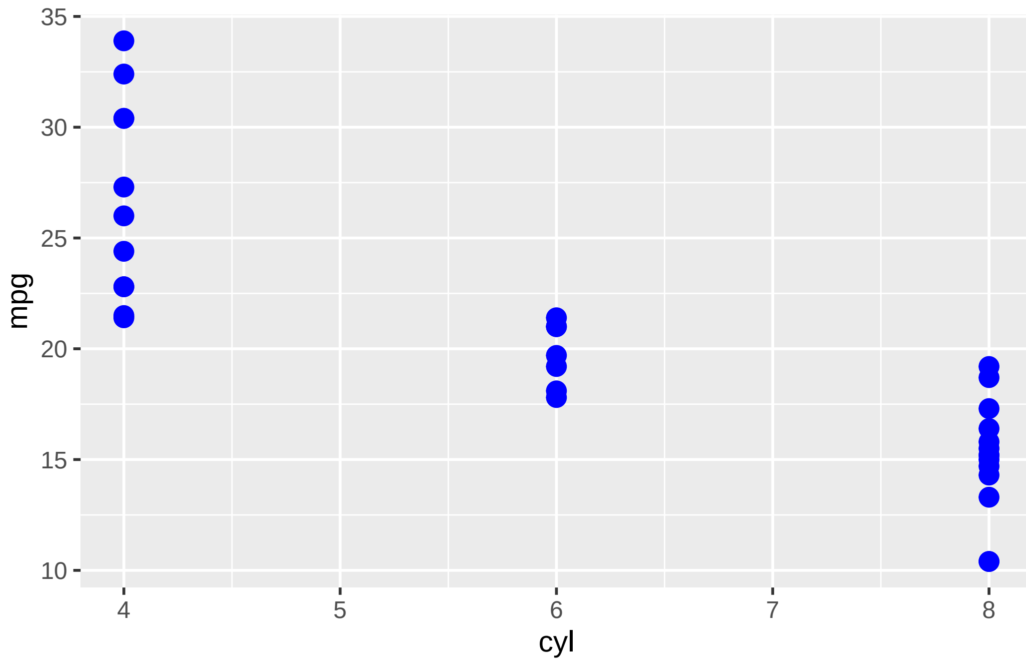
```
[1] "numeric"
```

Custom function

```r
# Define a function that doubles a number
double_it <- function(x) {
  x * 2
}

# Use the function
double_it(4576)
```

```
[1] 9152
```

```r
# Functions with multiple arguments
# Load ggplot2 package (install first if you don't have it)
library(ggplot2)

# Use the built-in dataset 'mtcars'
# We'll plot miles per gallon (mpg) vs number of cylinders (cyl)
ggplot(data = mtcars,               # Required argument: dataset
       mapping = aes(x = cyl, y = mpg)) +  # Required: aesthetics
  geom_point(color = "blue", size = 3)     # Optional arguments inside geom_point()
```



4.4 Piping (%>%)

Instead of nesting functions inside each other, you can write code step by step, which is often easier to read.

`%>%` (the "then" operator): pipes send an object from function to function.

Using **Tidyverse** + `%>%` you can do complex tasks in easy-to-read, step-by-step code.

Tidyverse is is a collection of R packages designed to work well together.

Example without a pipe

```
# Find the average mpg of cars with 6 cylinders
mean(subset(my.data, cyl == 6)$mpg)
```

```
[1] 19.74286
```

Example with a pipe

```
my.data %>%
  filter(cyl == 6) %>%
  pull(mpg) %>%
  mean()
```

```
[1] 19.74286
```

```
# save the avg mpg as an object
avg.mpg <- mtcars %>%
  filter(cyl == 6) %>%
  pull(mpg) %>%
  mean()

class(avg.mpg)
```

```
[1] "numeric"
```

References