

# REPRODUCIBLE RESEARCH WITH R

## STATISTICAL ANALYSIS WITH R USING RSTUDIO, GITHUB, KNITR AND SHINY

*Maja Založnik*



The Oxford Institute of  
Population Ageing

OXFORD – 19<sup>th</sup> November 2015

# OUTLINE

- Introduction
- Reproducibility
- RStudio
- Version control with git/GitHub
- Literate programming with knitr & R Markdown
- Dissemination with RPubS
- Interactivity with Shiny

- **Introduction**
- Reproducibility
- RStudio
- Version control with git/GitHub
- Literate programming with knitr & R Markdown
- Dissemination with RPubS
- Interactivity with Shiny

# OUTLINE

- Introduction
- **Reproducibility**
- RStudio
- Version control with git/GitHub
- Literate programming with knitr & R Markdown
- Dissemination with RPubS
- Interactivity with Shiny

# OUTLINE

- Introduction
- Reproducibility
- **RStudio**
- Version control with git/GitHub
- Literate programming with knitr & R Markdown
- Dissemination with RPubS
- Interactivity with Shiny

# OUTLINE

- Introduction
- Reproducibility
- RStudio
- **Version control with git/GitHub**
- Literate programming with knitr & R Markdown
- Dissemination with RPubS
- Interactivity with Shiny

# OUTLINE

- Introduction
- Reproducibility
- RStudio
- Version control with git/GitHub
- **Literate programming with knitr & R Markdown**
- Dissemination with RPubS
- Interactivity with Shiny

# OUTLINE

- Introduction
- Reproducibility
- RStudio
- Version control with git/GitHub
- Literate programming with knitr & R Markdown
- **Dissemination with RPubS**
- Interactivity with Shiny



# OUTLINE

- Introduction
- Reproducibility
- RStudio
- Version control with git/GitHub
- Literate programming with knitr & R Markdown
- Dissemination with RPubS
- **Interactivity with Shiny**

# REPRODUCIBILITY OF RESEARCH

- **Reproducibility vs Replicability of research?**

# REPRODUCIBILITY OF RESEARCH

- Reproducibility vs Replicability of research?
- *“The confirmation of results and conclusions from one study obtained independently in another”* (Jasny et al. 2011)

# REPRODUCIBILITY OF RESEARCH

- Reproducibility vs Replicability of research?
- *“The confirmation of results and conclusions from one study obtained independently in another”* (Jasny et al. 2011)
- *“[T]he independent verification of prior findings”* (Santer et al. 2011)

# REPRODUCIBILITY OF RESEARCH

- Reproducibility vs Replicability of research?
- *“The confirmation of results and conclusions from one study obtained independently in another”* (Jasny et al. 2011)
- *“[T]he independent verification of prior findings”* (Santer et al. 2011)
- **Levels of Replication**

# REPRODUCIBILITY OF RESEARCH

- Reproducibility vs Replicability of research?
- *“The confirmation of results and conclusions from one study obtained independently in another”* (Jasny et al. 2011)
- *“[T]he independent verification of prior findings”* (Santer et al. 2011)
- **Levels of Replication**
  1. Re-ask the question

# REPRODUCIBILITY OF RESEARCH

- Reproducibility vs Replicability of research?
- *“The confirmation of results and conclusions from one study obtained independently in another”* (Jasny et al. 2011)
- *“[T]he independent verification of prior findings”* (Santer et al. 2011)
- **Levels of Replication**
  1. Re-ask the question
  2. Re-do the experiment

# REPRODUCIBILITY OF RESEARCH

- Reproducibility vs Replicability of research?
- *“The confirmation of results and conclusions from one study obtained independently in another”* (Jasny et al. 2011)
- *“[T]he independent verification of prior findings”* (Santer et al. 2011)
- **Levels of Replication**
  1. Re-ask the question
  2. Re-do the experiment
  3. Re-analyse the data



# REPRODUCIBILITY OF RESEARCH

- Reproducibility vs Replicability of research?
- *“The confirmation of results and conclusions from one study obtained independently in another”* (Jasny et al. 2011)
- *“[T]he independent verification of prior findings”* (Santer et al. 2011)
- **Levels of Replication**
  1. Re-ask the question
  2. Re-do the experiment
  3. Re-analyse the data
  4. Reproduce the analysis

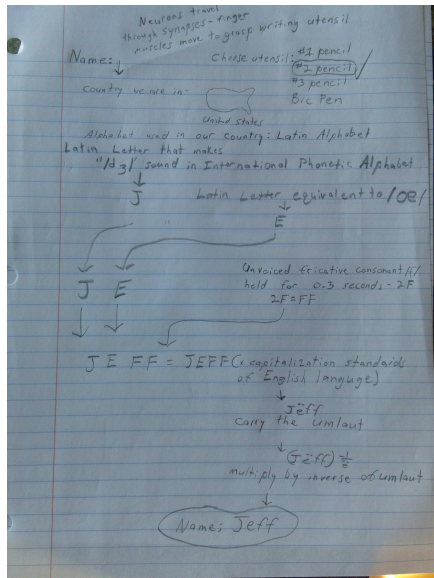
# REPRODUCIBILITY OF RESEARCH

- Reproducibility vs Replicability of research?
- *“The confirmation of results and conclusions from one study obtained independently in another”* (Jasny et al. 2011)
- *“[T]he independent verification of prior findings”* (Santer et al. 2011)
- Levels of Replication
  1. Re-ask the question
  2. Re-do the experiment
  3. Re-analyse the data
  4. **Reproduce the analysis**

# REPRODUCIBILITY: SHOW YOUR WORK!

imgur user TVsJeff:

*"A math teacher took points off for not showing all of my work. The next homework assignment i turned in looked like this. It was 45 pages long."*



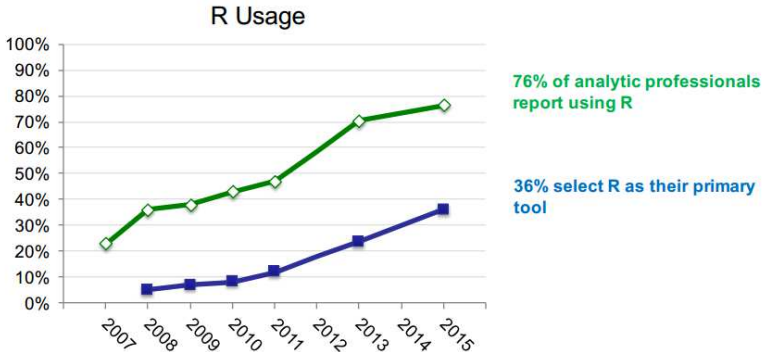
# REPRODUCIBILITY: DON'T USE EXCEL®?

	B	C	I	J	K	L	M
2			Real GDP growth				
3			Debt/GDP				
4	Country	Coverage	30 or less	30 to 60	60 to 90	90 or above	30 or less
26			3.7	3.0	3.5	1.7	5.5
27	Minimum		1.6	0.3	1.3	-1.8	0.8
28	Maximum		5.4	4.9	10.2	3.6	13.3
29							
30	US	1946-2009	n.a.	3.4	3.3	-2.0	n.a.
31	UK	1946-2009	n.a.	2.4	2.5	2.4	n.a.
32	Sweden	1946-2009	3.6	2.9	2.7	n.a.	6.3
33	Spain	1946-2009	1.5	3.4	4.2	n.a.	9.9
34	Portugal	1952-2009	4.8	2.5	0.3	n.a.	7.9
35	New Zealand	1948-2009	2.5	2.9	3.9	-7.9	2.6
36	Netherlands	1956-2009	4.1	2.7	1.1	n.a.	6.4
37	Norway	1947-2009	3.4	5.1	n.a.	n.a.	5.4
38	Japan	1946-2009	7.0	4.0	1.0	0.7	7.0
39	Italy	1951-2009	5.4	2.1	1.8	1.0	5.6
40	Ireland	1948-2009	4.4	4.5	4.0	2.4	2.9
41	Greece	1970-2009	4.0	0.3	2.7	2.9	13.3
42	Germany	1946-2009	3.9	0.9	n.a.	n.a.	3.2
43	France	1949-2009	4.9	2.7	3.0	n.a.	5.2
44	Finland	1946-2009	3.8	2.4	5.5	n.a.	7.0
45	Denmark	1950-2009	3.5	1.7	2.4	n.a.	5.6
46	Canada	1951-2009	1.9	3.6	4.1	n.a.	2.2
47	Belgium	1947-2009	n.a.	4.2	3.1	2.6	n.a.
48	Austria	1948-2009	5.2	3.3	-3.8	n.a.	5.7
49	Australia	1951-2009	3.2	4.9	4.0	n.a.	5.9
50							
51			4.1	2.8	2.8	=AVERAGE(L30:L44)	

FIGURE: Reinhart and Rogoff's Excel Spreadsheet (Source: [qz.com](http://qz.com))

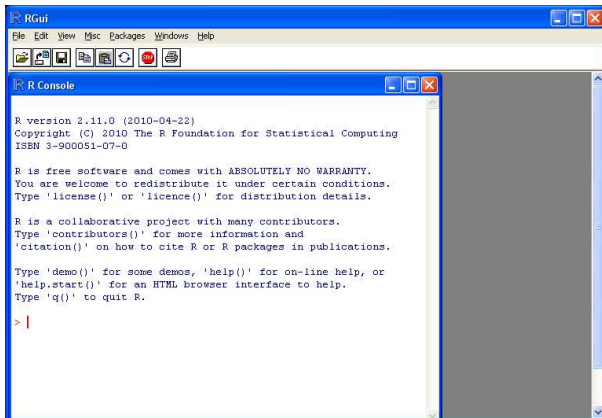
# GROWING POPULARITY OF R

- The proportion of analytic professionals using R continues to grow
  - Since 2010, R has been the #1 most-used data mining tool
- An increasing number of analytic professionals also select R as their primary tool
  - Since 2013, R has been #1 in primary tool rankings



**FIGURE:** 2015 Data Science Survey Results - N=1,220 (Source: Karl Rexer 2015)

# R IDEs THEN AND NOW



# R IDEs THEN AND NOW

~/Dropbox/XtraWork/RepRes - master - RStudio

File Edit Code View Plots Session Build Debug Tools Help

Go to file/function

LisaMaps.Rmd x RMarkdown.Rmd x

```
69 {r}
70 {ln(iris$Petal.Width ~ iris$Petal.Length)$coefficients}
71 {r}
72 {r}
73
74 OK, not we can do the same plot as before, but add colours and the line. And
  because this is pretty straightforward, I won't bore you with the code, but only
  show you the plot instead:
75
76 {r, echo=FALSE}
77 plot(iris$Petal.Length, iris$Petal.Width,
78      col=c("red", "green", "blue")[unclass(iris$Species)],
79      xlab=c("Petal length"),
80      ylab=c("Petal width"),
81      main="Iris Data")
82 abline(ln(iris$Petal.Width ~ iris$Petal.Length)$coefficients, col="black")
83
84 ...
85
86 ### More to come...
77.1 | Chunk 4 2 R Markdown
```

Environment History Git

Staged Status Path

- 2015-11-19-Oxford-ReproducibleResearchR.pdf
- 2015-11-19-Oxford-ReproducibleResearchR.tex
- 2015-11-19-Oxford-ReproducibleResearchRNotes.tex
- 2015-11-19-Oxford-ReproducibleResearchRStreamlined.pdf
- 2015-11-19-Oxford-ReproducibleResearchRStreamlined.tex
- cache/
- Data/Rexer Data Science Survey Highlights Sep-2015.pdf
- Scripts/LisaMaps.Rmd
- Scripts/LisaMaps.docx
- Scripts/LisaMaps.html

Files Plots Packages Help Viewer

Zoom Export

Publish

### Iris Data

The figure is a scatter plot titled "Iris Data". The x-axis is labeled "Petal length" and ranges from 1 to 7. The y-axis is labeled "Petal width" and ranges from 0.5 to 2.5. The data points are colored based on the species: red for setosa, green for versicolour, and blue for virginica. A black linear regression line is plotted through the data, showing a positive correlation between petal length and petal width.

Console

~/Dropbox/XtraWork/RepRes/

R is a collaborative project with many contributors.  
Type 'contributors()' for more information and  
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or  
'help.start()' for an HTML browser interface to help.  
Type 'q()' to quit R.

```
> plot(iris$Petal.Length, iris$Petal.Width,
+      col=c("red", "green", "blue")[unclass(iris$Species)],
+      xlab=c("Petal length"),
+      ylab=c("Petal width"),
+      main="Iris Data")
> abline(ln(iris$Petal.Width ~ iris$Petal.Length)$coefficients, col="black")
>
```

- Probably the most popular IDE for R
- Launched February 2011
- January 2012 - Project system and Version control integration (git/SVN)
- May 2012 - knitr & R Markdown publishing tools added
- June 2012 - publish to RPubs integration
- December 2013 - Shiny integration
- October 2014 - direct publishing to shinyapps.io



# VERSION CONTROL: GIT



FIGURE: [xkcd](#)

# GIT/GITHUB FOR REPRODUCIBLE RESEARCH

# GIT/GITHUB FOR REPRODUCIBLE RESEARCH

- Full documentation

# GIT/GITHUB FOR REPRODUCIBLE RESEARCH

- Full documentation
- Collaboration

# GIT/GITHUB FOR REPRODUCIBLE RESEARCH

- Full documentation
- Collaboration
- Dissemination

# GIT/GITHUB FOR REPRODUCIBLE RESEARCH

- Full documentation
- Collaboration
- Dissemination
- Backup

# GIT/GITHUB FOR REPRODUCIBLE RESEARCH

- Full documentation
- Collaboration
- Dissemination
- Backup
- [RStudio integration](#)

# GIT/GitHub FOR REPRODUCIBLE RESEARCH

- Full documentation
- Collaboration
- Dissemination
- Backup
- [RStudio integration](#)
- [GitHub](#) - the Facebook of code



# GIT/GITHUB FOR REPRODUCIBLE RESEARCH

- Full documentation
- Collaboration
- Dissemination
- Backup
- [RStudio integration](#)
- [GitHub](#) - the Facebook of code
- But [click here for five free private repos!](#)

# LITERATE PROGRAMMING AND KNITR

*“Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do.”*

Donald Knuth (1984)

# LITERATE PROGRAMMING AND KNITR

*“Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do.”*

Donald Knuth (1984)



# LITERATE PROGRAMMING AND KNITR

- Human readable

# LITERATE PROGRAMMING AND KNITR

- Human readable
  - Pure code: WHAT & HOW but not WHY
  - Pure text: WHAT & WHY but not HOW

# LITERATE PROGRAMMING AND KNITR

- Human readable
  - Pure code: WHAT & HOW but not WHY
  - Pure text: WHAT & WHY but not HOW
- Script all your code!

# LITERATE PROGRAMMING AND KNITR

- Human readable
  - Pure code: WHAT & HOW but not WHY
  - Pure text: WHAT & WHY but not HOW
- Script all your code!
- Consistent coding style e.g.:
  - [Google style guide](#)
  - [Hadley Wickham's style guide](#)

# LITERATE PROGRAMMING AND KNITR

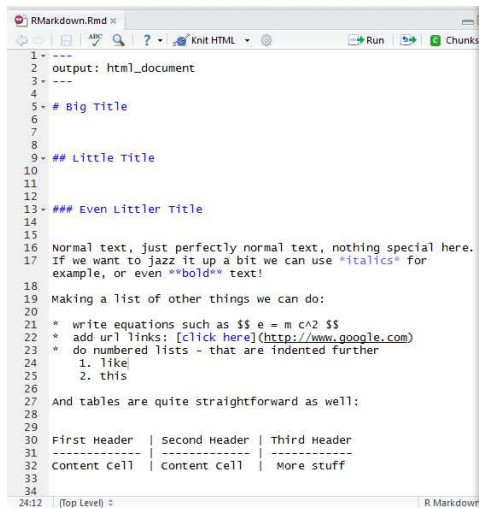
- Human readable
  - Pure code: WHAT & HOW but not WHY
  - Pure text: WHAT & WHY but not HOW
- Script all your code!
- Consistent coding style e.g.:
  - [Google style guide](#)
  - [Hadley Wickham's style guide](#)
- Commenting



# LITERATE PROGRAMMING AND KNITR

- Human readable
  - Pure code: WHAT & HOW but not WHY
  - Pure text: WHAT & WHY but not HOW
- Script all your code!
- Consistent coding style e.g.:
  - [Google style guide](#)
  - [Hadley Wickham's style guide](#)
- Commenting
- knitting

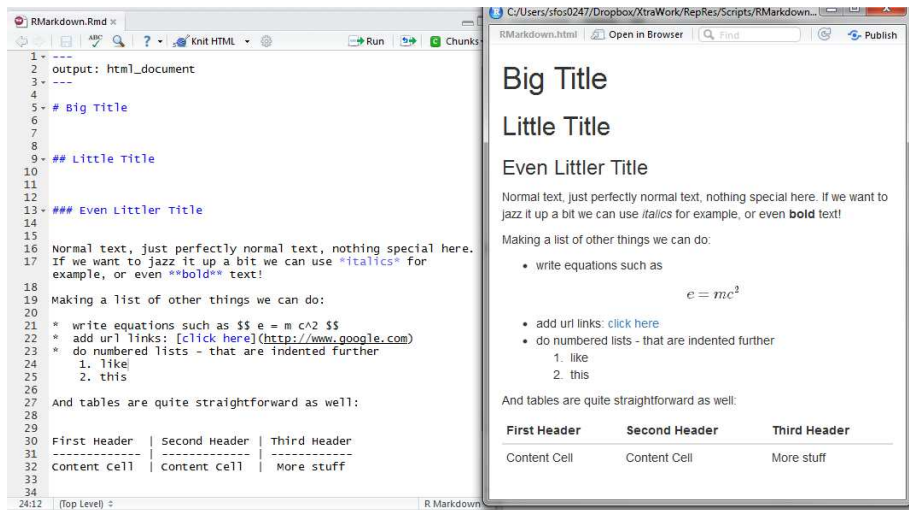
# KNITTING WITH MARKDOWN AND R



```
1  ---
2  output: html_document
3  ---
4
5  # Big Title
6
7
8
9  ## Little Title
10
11
12
13  ### Even Littler Title
14
15
16  Normal text, just perfectly normal text, nothing special here.
17  If we want to jazz it up a bit we can use italics for
18  example, or even bold text!
19
20  Making a list of other things we can do:
21
22  * write equations such as  $e = mc^2$ 
23  * add url links: [click here](http://www.google.com)
24  * do numbered lists - that are indented further
25    1. like
26    2. this
27
28  And tables are quite straightforward as well:
29
30  First Header | Second Header | Third Header
31  -----|-----|-----
32  content cell | content cell | More stuff
33
34
```

24:12 (Top Level) R Markdown

# KNITTING WITH MARKDOWN AND R



The image displays the RStudio interface with an R Markdown document. The left pane shows the source code, and the right pane shows the rendered HTML output.

**Source Code (Left Pane):**

```
1 ---  
2 output: html_document  
3 ---  
4  
5 # Big Title  
6  
7  
8  
9 ## Little Title  
10  
11  
12  
13 ### Even Littler Title  
14  
15  
16 Normal text, just perfectly normal text, nothing special here.  
17 If we want to jazz it up a bit we can use italics for  
18 example, or even bold text!  
19  
20 Making a list of other things we can do:  
21  
22 * write equations such as  $e = mc^2$   
23 * add url links: [click here](http://www.google.com)  
24 * do numbered lists - that are indented further  
25   1. like  
26   2. this  
27  
28 And tables are quite straightforward as well:  
29  
30 | First Header | Second Header | Third Header |  
31 |-----|-----|-----|  
32 | Content Cell | Content Cell | More stuff |  
33  
34
```

**Rendered Output (Right Pane):**

## Big Title

### Little Title

#### Even Littler Title

Normal text, just perfectly normal text, nothing special here. If we want to jazz it up a bit we can use *italics* for example, or even **bold** text!

Making a list of other things we can do:

- write equations such as
$$e = mc^2$$
- add url links: [click here](http://www.google.com)
- do numbered lists - that are indented further
  1. like
  2. this

And tables are quite straightforward as well:

First Header	Second Header	Third Header
Content Cell	Content Cell	More stuff

[Publish on RPubS](#)

# INTERACTIVE GRAPHICS WITH R

SHINY

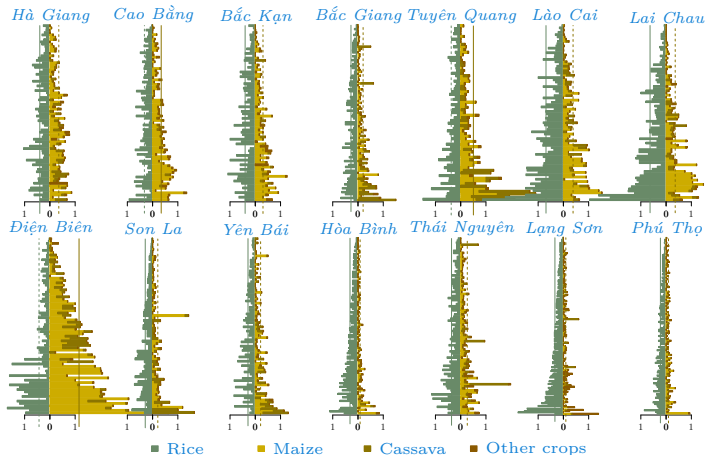
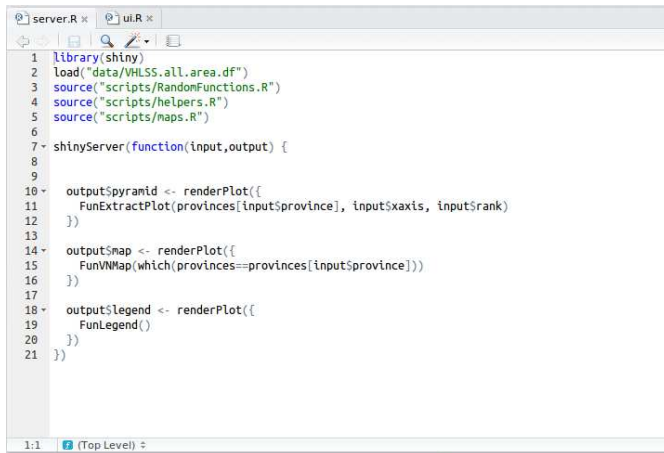


FIGURE: Areas of rice planted (left) and other crops (right) on individual farms for each province (in ha) (data: VHLSS 2012)

# INTERACTIVE GRAPHICS WITH R

## SHINY - SERVER.R



```
1 library(shiny)
2 load("data/VHLSS.all.area.df")
3 source("scripts/RandomFunctions.R")
4 source("scripts/helpers.R")
5 source("scripts/maps.R")
6
7 shinyServer(function(input,output) {
8
9
10  output$pyramid <- renderPlot({
11    FunExtractPlot(provinces[input$province], input$xaxis, input$rank)
12  })
13
14  output$map <- renderPlot({
15    FunVMap(which(provinces==provinces[input$province]))
16  })
17
18  output$legend <- renderPlot({
19    FunLegend()
20  })
21 })
```

1:1 (Top Level) ↕

FIGURE: Content of `server.R` file for VHLSS shiny app

# INTERACTIVE GRAPHICS WITH R

SHINY - UI.R

```
server.R x ui.R x
1 library(shiny)
2 load("data/VHLSS.all.area.df")
3 source("scripts/helpers.R")
4
5 shinyUI(fluidPage(
6   titlePanel("VHLSS: Rice and other crop production in Northern Vietnam"),
7
8   fluidRow(
9     column(12,
10      "Individual farm cropland area planted with rice or other annual crops", br(),
11      "[Data: The Vietnam Household Living Standard Survey 2010]", br(), br(), br()),
12
13     fluidRow(
14       column(3,
15         selectInput("province", em("Select a province from the menu:"),
16           choices = province.names),
17         selectInput("rank", em("Sort farms by size of:"),
18           choices = c("Total cropland", "Rice area", "Other crops area")),
19         checkboxInput("xaxis", em("Keep constant x-axis?"), TRUE),
20         plotOutput("map", height="180px"), br(),
21         plotOutput("legend", height="110px")),
22
23       column(9,
24         plotOutput("pyramid", height="450px"))))
25 )
```

1:1 (Top Level) ↕

FIGURE: Content of ui.R file for VHLSS shiny app

# INTERACTIVE GRAPHICS WITH R

- [Iris example again](#)
- [3D rendering of mortality data](#)
- [“Hans Rosling” style chart](#)
- [showmeshiny.com](http://showmeshiny.com)



# LIST OF HELPFUL LINKS AND FREE RESOURCES

- Christopher Gandrud's *Reproducible Research with R and RStudio*
- Coursera [Data Science Specialisation](#)
- [GitHub](#) & [academic discount link](#)
- [R markdown](#) and [knitr](#) resources
- [RPods](#)
- [RPresentations](#) & [Slidify](#)
- [Shiny](#) tutorial
- [R-bloggers](#)
- [Stackoverflow](#)
- [This presentation](#) on github (RepRes)