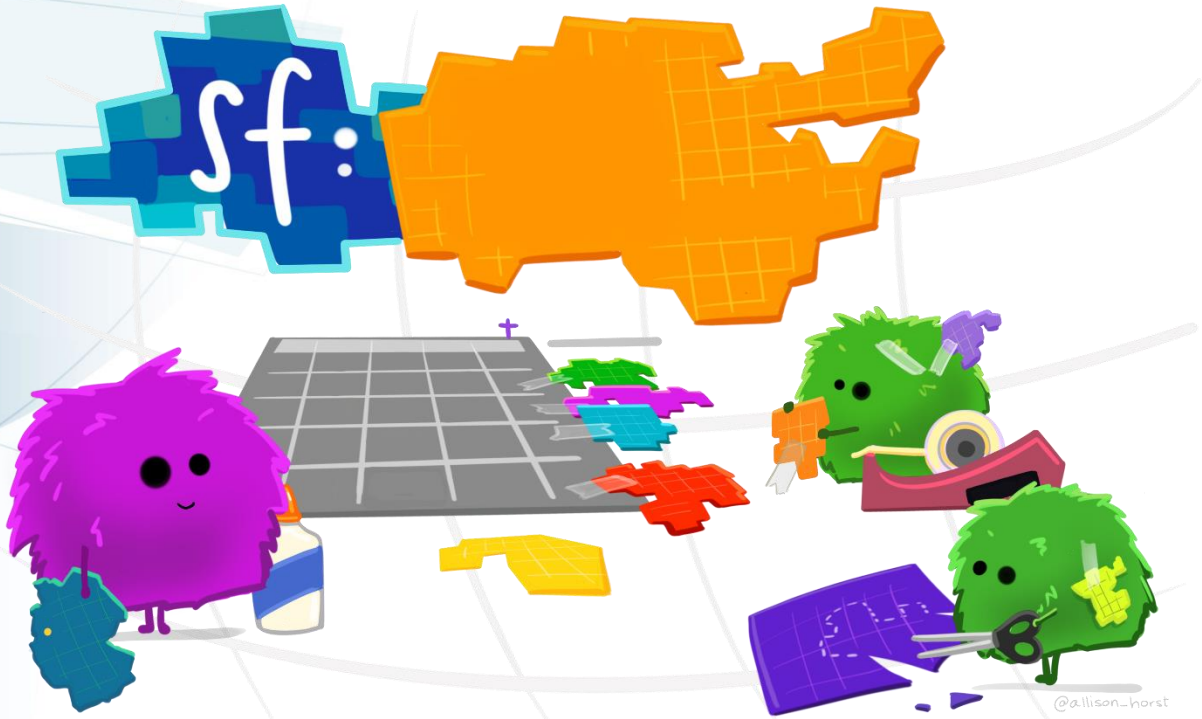
International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

science for global insight

Spatial data and analysis in R

ESM – CDAT course series



(Artwork by @allison_horst)

Martin Jung, PhD
(jung@iiasa.ac.at)

Course plan

Introduction talk
(14:00 – 14:45pm, 22th October 2020)

Self study tutorials
(online self paced, link at end of slides)

All slides and materials online

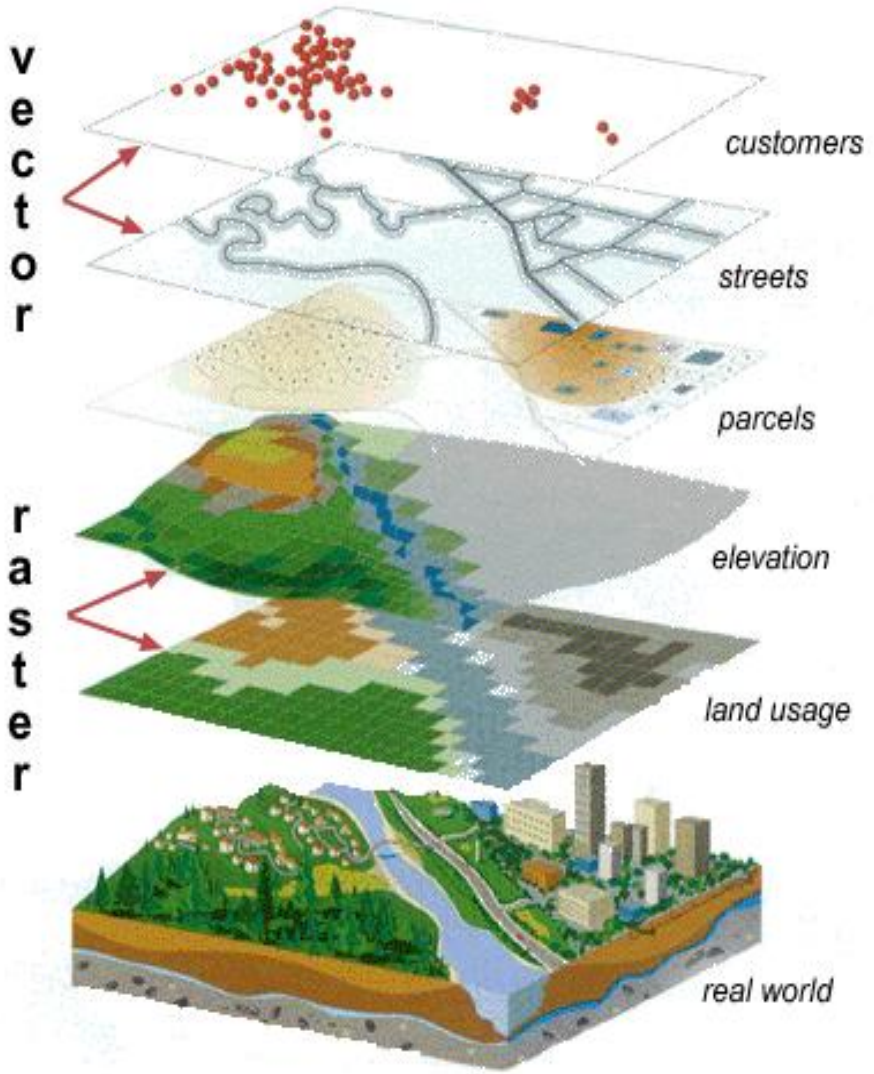
https://tinyurl.com/CDATSpatR

What is GIS?

*A geographic information system (**GIS**) is a system designed to capture, store, manipulate, analyze, manage, and present types of geographical data.*




Types of spatial data



Source: maprabu.blogspot.com

Format:
*.shp, *.gpkg, *.gpx, *.kml, ...

Format:
*.tif, *.vrt, *.hdr, *.asc, ...

Vector

Advantage: Accuracy, more visually pleasing

Disadvantage: Space-inefficient. Every vertex needs to be stored. Algorithms computational intensive.

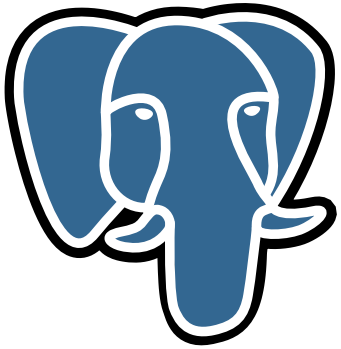
Raster

Advantage: Geogr. Position associated with data, easier for analysis

Disadvantage: Resolution dependent on cell-size. Lack of attributes, MAUP

Spatial databases

SpatiaLite



PostgreSQL & PostGIS

And many more...

Stop using shapefiles!

Multifile system (.shp,.shx,.dbf,.prj, …)

Limited to 2GB (4GB)

Attribute names limitation

Etc…

http://switchfromshapefile.org/

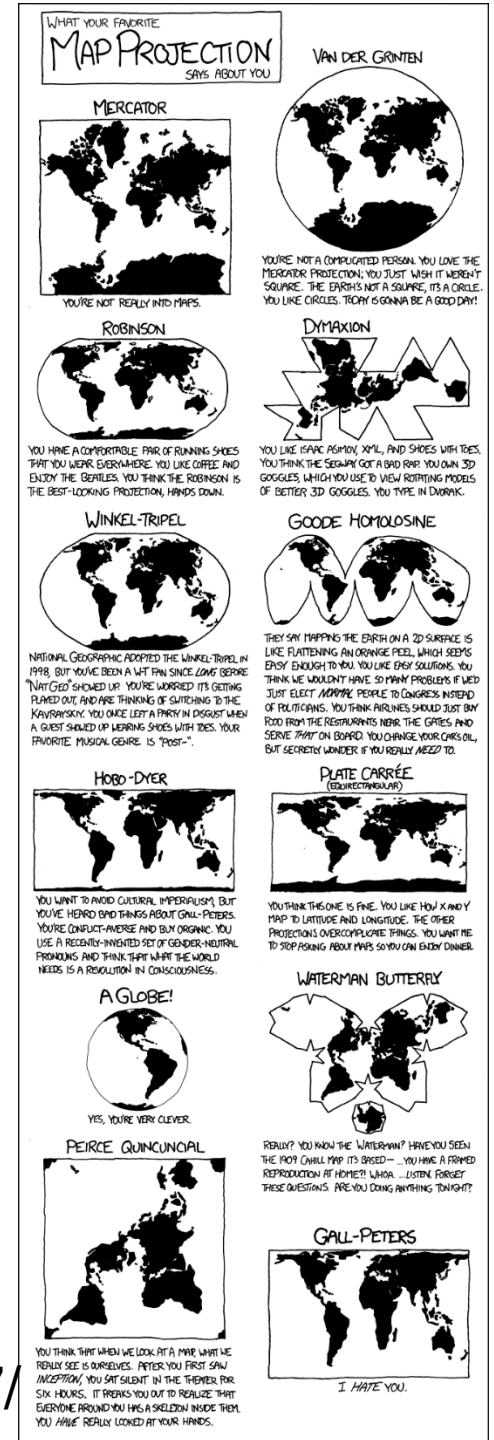
Solution → OGC Geopackages

Geographic projections

Spatial data requires a projection

Choosing an appropriate geographic projection is important

- Meter or degree based?
- Tradeoff between shape, area or distance distortion
- Aesthetics vs accuracy



Source: https://xkcd.com/977/

Why use R for spatial analyses?

- ✓ Open source
- ✓ Efficiency ('Don't repeat yourself')
- ✓ Cross system availability (Win,*Nix, MacO$
- ✓ Extendable and rich functionality
- ✓ Clean coding (also for 'tidy' data concept)
- ✓ Parallel computing support
- ✓ Integration of C, C++ code for speed

Many spatial packages

ELSEVIER

Environmental Modelling & Software

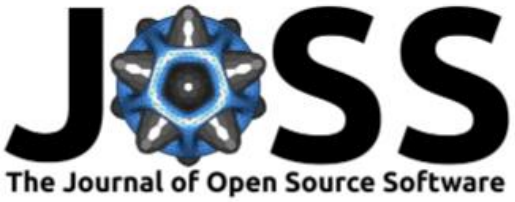
Volume 133, November 2020, 104799

Position Paper

Harmonise and integrate heterogeneous areal data with the R package arealDB

Steffen Ehrmann [a, d] ✉, Ralf Seppelt [b, c], Carsten Meyer [a, c, d] ✉

Source: https://doi.org/10.1016/j.envsoft.2020.104799



geemap: A Python package for interactive mapping with Google Earth Engine

Qiusheng Wu[1]

1 Department of Geography, University of Tennessee, Knoxville, TN 37996, United States

DOI: 10.21105/joss.02305

One comprehensive list of spatial packages

https://cran.r-project.org/web/views/Spatial.html

Why/When not to use R for spatial analyses?

- R can be slow
- Many (sp) packages not memory efficient
- Often little support
- No GUI
- Greater proficiency in other languages

(Personal opinion)

The diversity of open source GIS solutions is both its greatest strength and weakness

The backbone of most open-source GIS

OGC®

Making location count.

Standards like WMS, KML, GML, SFC

PROJ

GEOS Geometry Engine Open Source

C/C++ libraries

R as a GIS

Main packages: 'sp', 'raster' and 'rgdal' still go-to functions to use

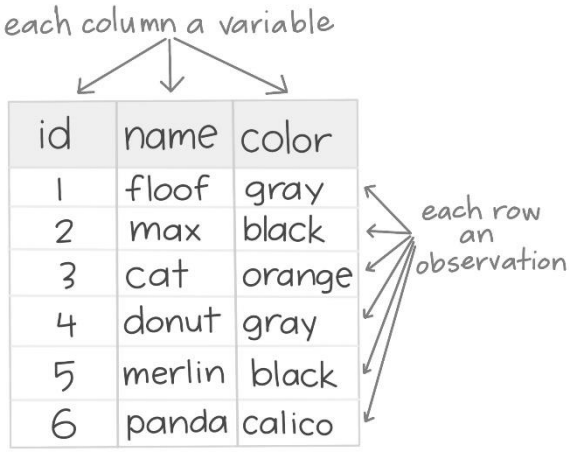
Problem: Each have their own object-based model, often inefficient code

"TIDY DATA is a standard way of mapping the meaning of a dataset to its structure."

—HADLEY WICKHAM

In tidy data:

- each variable forms a column
- each observation forms a row
- each cell is a single measurement



Wickham, H. (2014). Tidy Data. Journal of Statistical Software 59 (10). DOI: 10.18637/jss.v059.i10

Artwork by @allison_horst

Tidy data and simple features

Simple Features are a set of OGC standards how spatial (vector) data is to be stored

Source: https://r-spatial.github.io/sf/articles/sf1.html

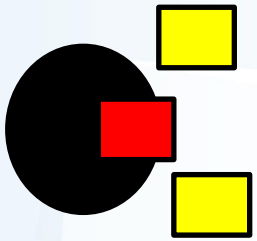
```
## Simple feature collection with 100 features and 6 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## epsg (SRID):    4267
## proj4string:    +proj=longlat +datum=NAD27 +no_defs
## precision:      double (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

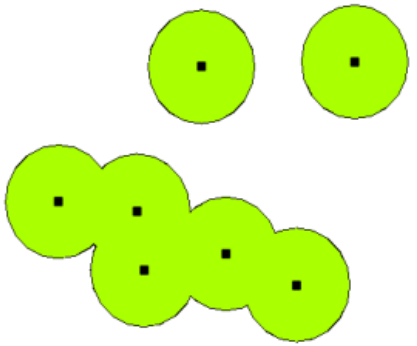
Simple feature geometry list–colum (sfc)

Simple feature geometry (sfg)

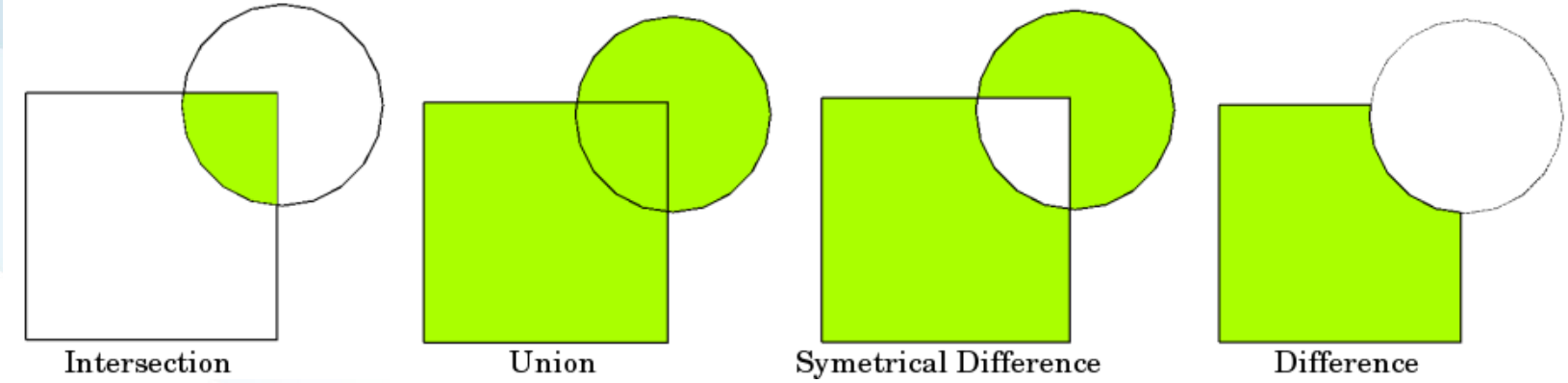
Spatial analyses – vector data



Spatial selections



Buffering



Source: QGIS documentation

Example code in R using 'sf '

```
World %>%
        st_transform(crs = 54009) %>%
        st_buffer(1000) %>%
        st_intersects(hotspots) %>%
        group_by(hotspot_name) %>%
                summarise(
                geometry = st_union(geometry),
                area = st_area(geometry)
                                )
```

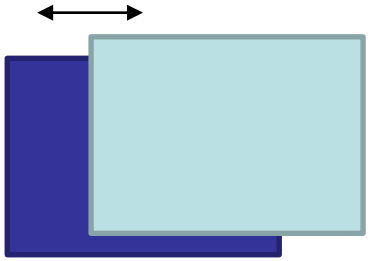
Spatial analyses – raster data

Examples

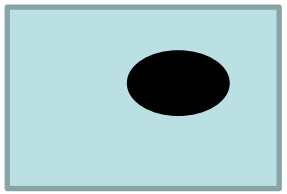
- Aggregations, disaggregations
- Region growth, reclassifications
- Band arithmetic (NDVI etc)
- Terrain analyses (Slope, Aspect, Curvature)
- …

Common spatial tasks I do in R

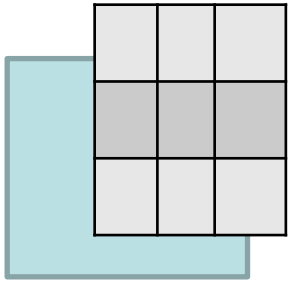
Aligning raster input data



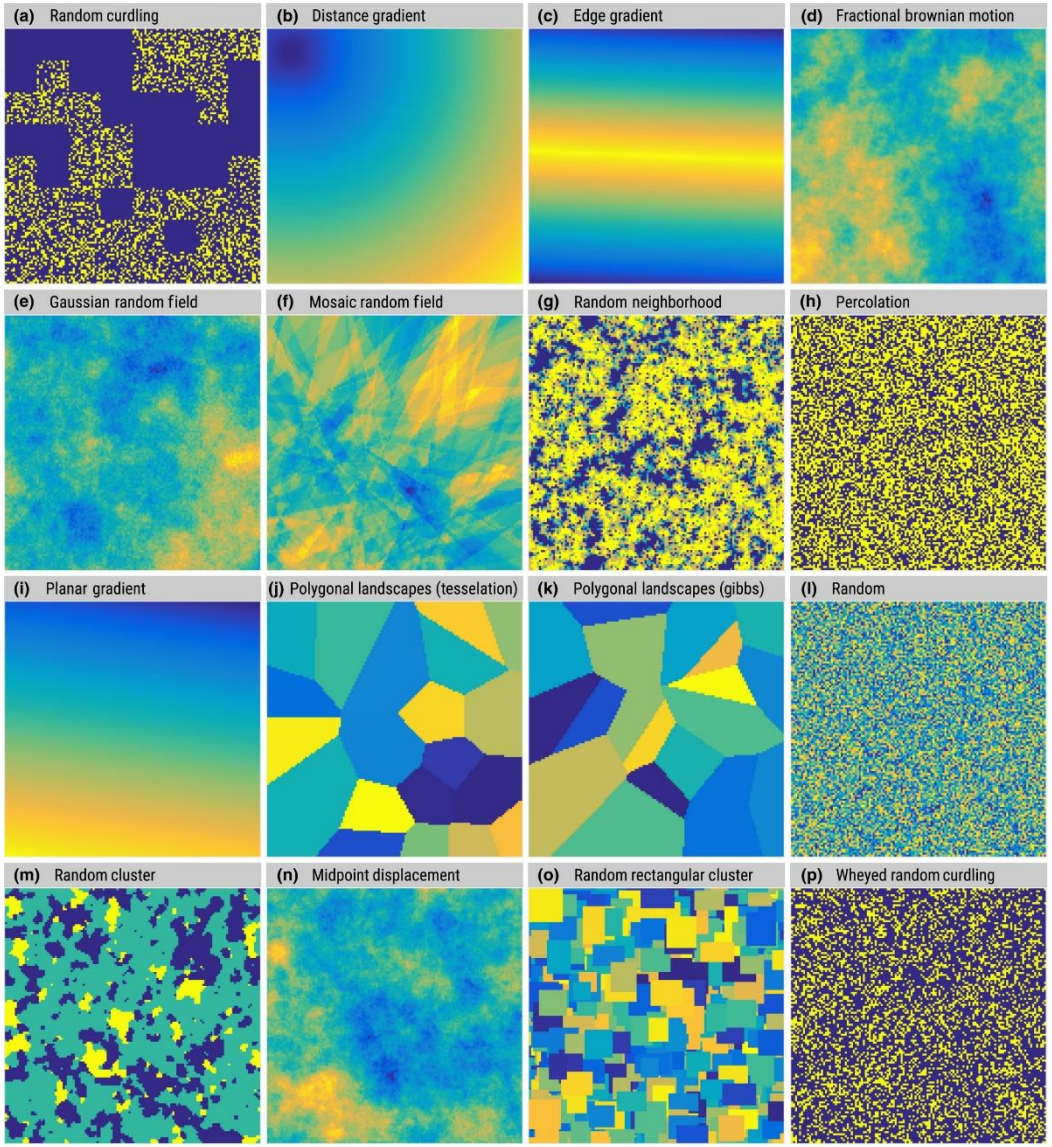
Extracting zonal statistics



Joining spatial and non-spatial data



Examples: Neutral landscapes



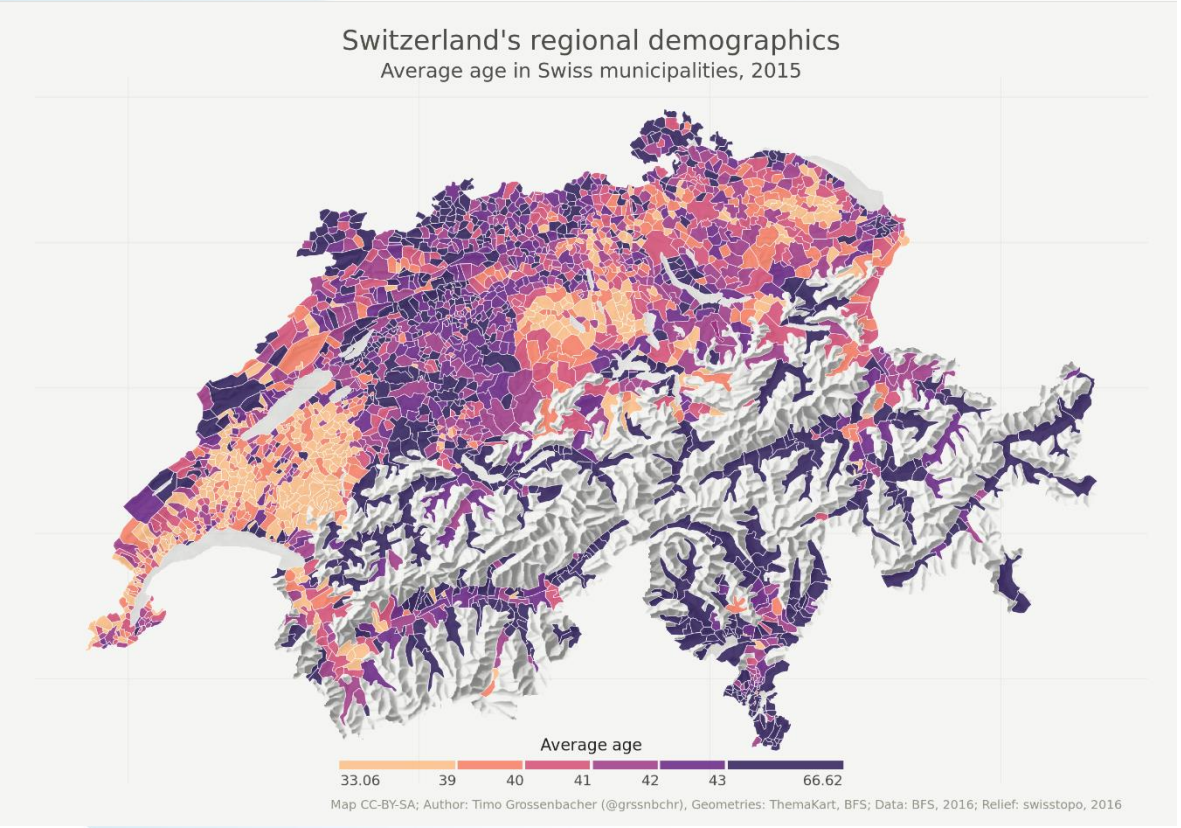
Source:
https://ropensci.github.io/NLMR/

Example: Landscape metrics

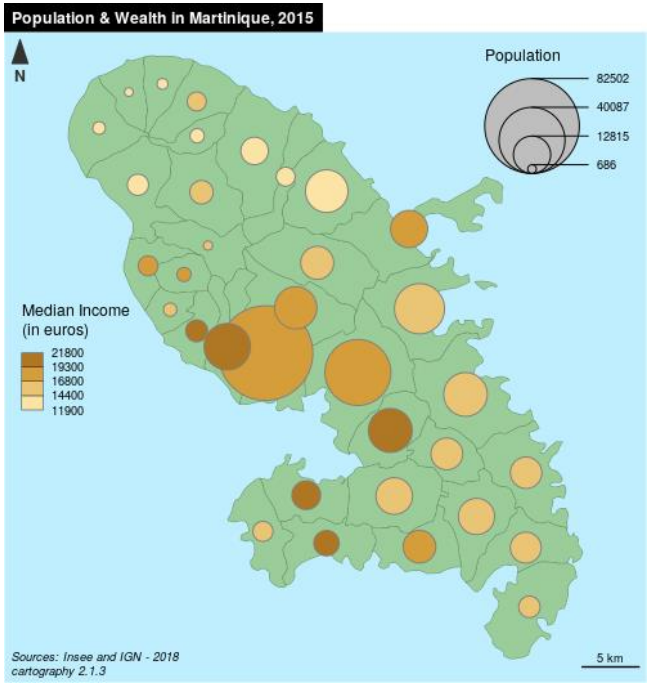
```
# list all available metrics
list_lsm()
#> # A tibble: 132 x 5
#>    metric name                                type                level function_name
#>    <chr>  <chr>                               <chr>               <chr> <chr>
#>  1 area   patch area                          area and edge met… patch lsm_p_area
#>  2 cai    core area index                     core area metric    patch lsm_p_cai
#>  3 circle related circumscribing circle       shape metric        patch lsm_p_circle
#>  4 contig contiguity index                    shape metric        patch lsm_p_contig
#>  5 core   core area                           core area metric    patch lsm_p_core
#>  6 enn    euclidean nearest neighbor dis…     aggregation metric  patch lsm_p_enn
#>  7 frac   fractal dimension index             shape metric        patch lsm_p_frac
#>  8 gyrate radius of gyration                  area and edge met… patch lsm_p_gyrate
#>  9 ncore  number of core areas                core area metric    patch lsm_p_ncore
#> 10 para   perimeter-area ratio                shape metric        patch lsm_p_para
#> # … with 122 more rows
```

Source:
https://r-spatialecology.github.io/landscapemetrics/

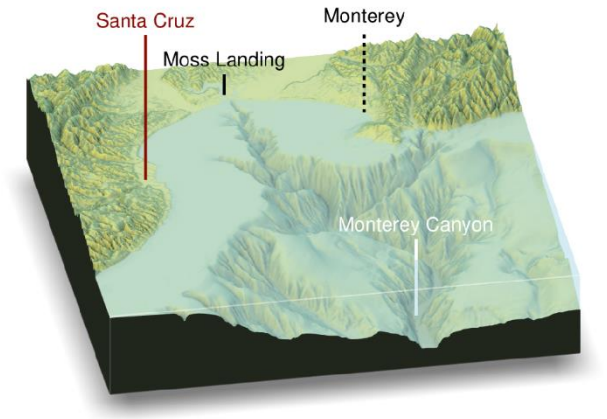
Making maps in R



Source: https://timogrossenbacher.ch/2016/12/beautiful-thematic-maps-with-ggplot2-only/



Source:
http://riatelab.github.io/cartography



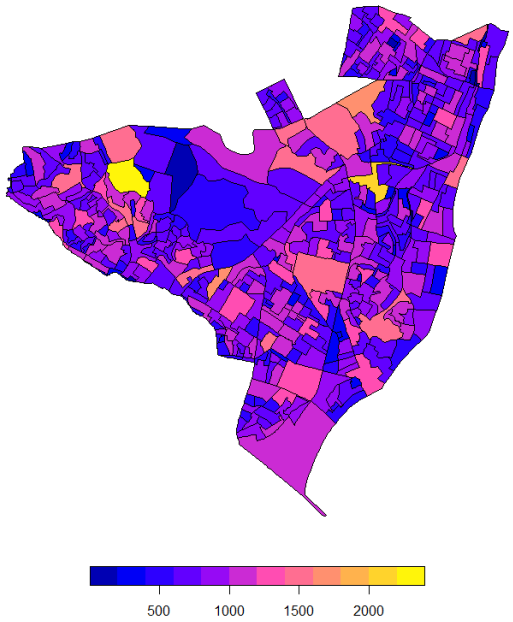
Source:
https://github.com/tylermorganwall/rayshader

Spatial statistics

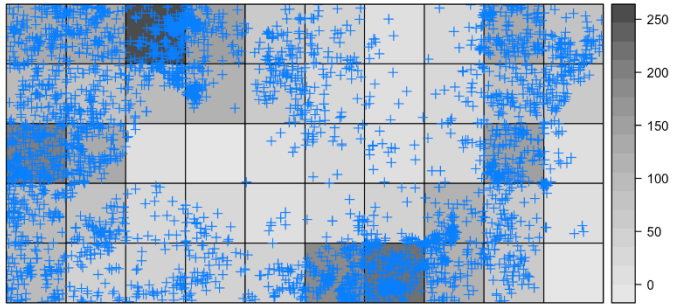
(Not covered in the online course!)

Geographically weighted regressions, Kriging, Network analyses, Spatial clustering, Machine learning

…



A lot of data has spatial structure!



What to do if things don’t work

Too slow

→ Check memory requirements, consider tiling

No Function

→ Check external tools. Is there a wrapper?

Visualization

→ Use QGIS for quick queries

Free online books and materials

Welcome

This is the online home of *Geocomputation with R*, a book on geographic data analysis, visualization and modeling.

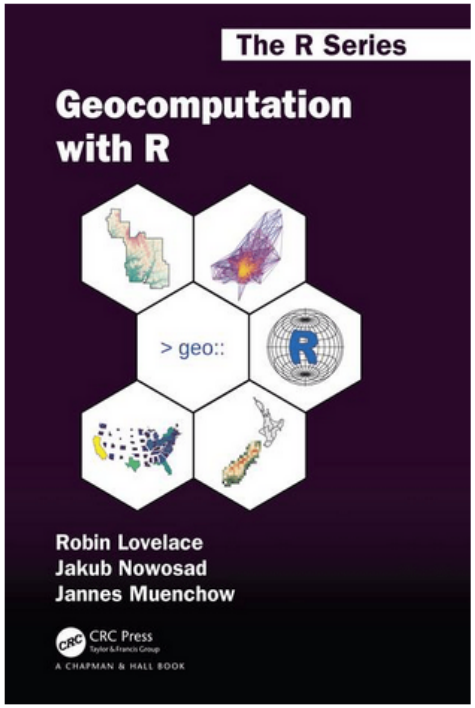
Note: This book has now been published by CRC Press in the R Series. You can buy the book from CRC Press, Wordery, or Amazon.

Inspired by **bookdown** and the Free and Open Source Software for Geospatial (FOSS4G) movement, this book is open source. This ensures its contents are reproducible and publicly accessible for people worldwide.

The online version of the book is hosted at geocompr.robinlovelace.net and kept up-to-date by GitHub Actions, which provides information on its 'build status' as follows:

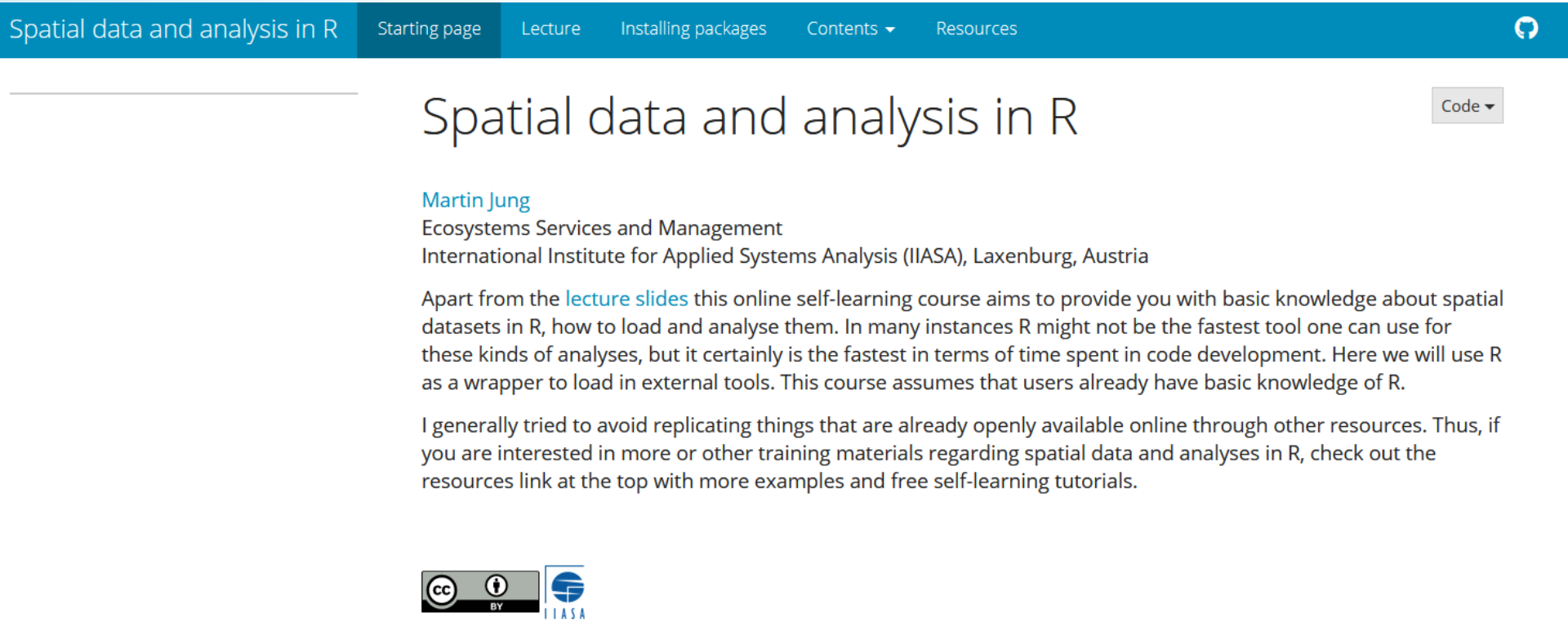
Render-Book-from-master passing

This version of the book was built on GH Actions on 2020-10-06.



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

Online course materials



https://tinyurl.com/CDATSpatR

Thank you for your attention.

Good success with your spatial analyses!