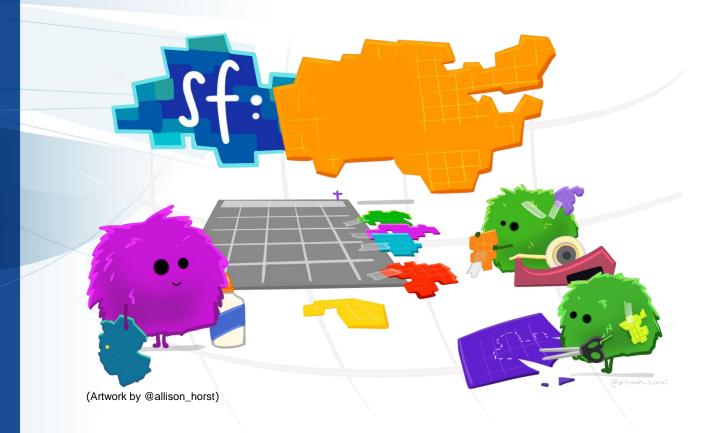
# Spatial data and analysis in R ESM – CDAT course series





## Course plan

Introduction talk (14 - 15pm, 22<sup>th</sup> October 2020)

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

All slides and materials online



#### What is GIS?

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







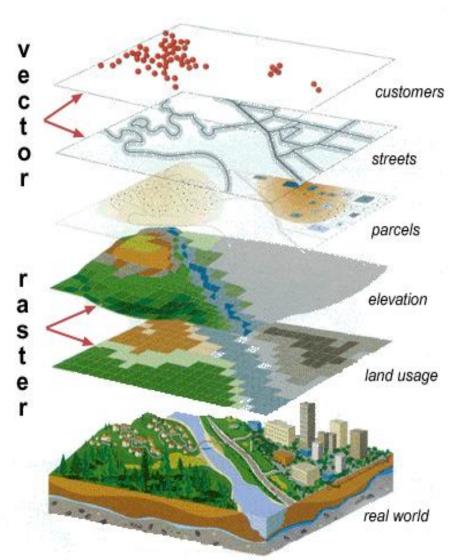








# Types of spatial data



#### 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

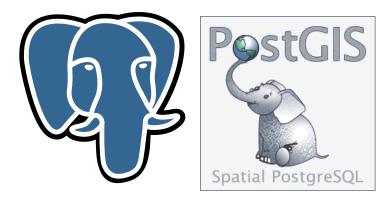
Disadvantage: Resolution dependent on cellsize. Lack of attributes, MAUP



# Spatial databases







PostgreSQL & PostGIS



# Stop using shapefiles!



```
Multifile system (.shp,.shx,.dbf,.prj, ...)
                 http://switchfromshapefile.org/
Limited to 2GB (4GB)
```

Attribute names limitation

Etc...

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







MERCATOR PROJECTION; YOU JUST WISH IT WEREN' SQUARE. THE EARTH'S NOT A SQUARE, IT'S A ORCLE YOU LIKE CIRCLES, TODAY IS GONNA BE A GOOD DAY



THAT YOU WEAR EVERYWHERE. YOU LIKE COFFEE AND ENJOY THE BEATLES, YOU THINK THE ROBINSON IS THE BEST-LOOKING PROTECTION, HANDS DOWN



YOU THINK THE SEGMAY GOT A RAD RAP YOU OWN 3D GOGGLES. WHICH YOU USE TO VIEW ROTATING MODELS OF BETTER 3D GOGGLES YOU TYPE IN DURRAK



1998. BUT YOU'VE BEEN A WIT FAN SINCE LONG BEFORE NATGEO" SHOWED UP. YOU'RE WORRIED IT'S GETTING AMED OUT, AND ARE THINKING OF SLITTCHING TO THE KAURAYSKIY YN I ONCE LEFT A PARTY IN DISGIKT WHEN GUEST SHOWED UP WEARING SHOES WITH TOES. YOUR



FASY FNOUGHTONOU. YOU LIKE FASY SOLUTIONS, YO THINK WE WOULDN'T HAVE SO MANY PRORIEKS IF WE THAT FLECT MORNAY PROPER TO CONCRESS INSTEAD OF PALITICIANS. YOU THINK AIRLINES SHOULD TIKE RIM FOOD FROM THE RESTAURANTS NORD THE GATES AND SERVE THAT ON BOARD. YOU CHANGE YOUR CAR'S OIL



YOU'VE HEARD RAD THINGS ARRITE GALL - DETERS YOU'RE CONFLICT-AVERSE AND BUY ORGANIC. YOU LISE A RECENTLY-INVENTED SET OF GENDER-NEUTRAL PROHOUNS AND THINK THAT WHAT THE WORLD



YOUTHINK THIS ONE IS FINE. YOU LIKE H MAP TO LATTTUDE AND LONGITUDE. THE OTHER PROTECTIONS OVERCOMPLICATE THINGS. YOU WANT HE TO STOP ASKING ABOUT MAPS SO YOU CAN ENDOY DINNE



THE 1909 CAHILL MAP IT'S BASED - ... YOU HAVE A FRAMED REPRODUCTION AT HOME?! WHOA. ... LISTEN, FORGET FIRST QUESTIONS ARE YOUT DOING ANYTHING TONKY-IT



REALLY SEE IS ODRIGHVES. APPER YOU FIRST SALV SIX HINURS IT FREAKS YOU OUT TO REALIZE THAT EVERYONE AROUND YOU HAS A SKELETON INSIDE THEM









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



#### Environmental Modelling & Software

Volume 133, November 2020, 104799



Position Paper

# Harmonise and integrate heterogeneous areal data with the R package arealDB

Steffen Ehrmann <sup>a, d</sup>  $\stackrel{\triangle}{\sim}$   $\stackrel{\boxtimes}{\sim}$ , Ralf Seppelt <sup>b, c</sup>, Carsten Meyer <sup>a, c, d</sup>  $\stackrel{\triangle}{\sim}$   $\stackrel{\boxtimes}{\sim}$ 

Source: <a href="https://doi.org/10.1016/j.envsoft.2020.104799">https://doi.org/10.1016/j.envsoft.2020.104799</a>





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

Qiusheng Wu<sup>1</sup>

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.rproject.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

OGG®
Making location count.

Standards like WMS, KML, GML, SFC



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

(	each co	lumn a v	ariable	
	id name		color	
	1	floof	gray	< each row
	2	max	black	← an
	3	cat	orange	Mobservatio
	4	donut	gray	2//
	5	merlin	black	4/
	6	panda	calico	1

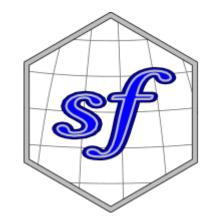
Wickham, H. (2014). Tidy Data. Journal of Statistical Software 59 (10). DOI: 10.18637/jss.v059.i10

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

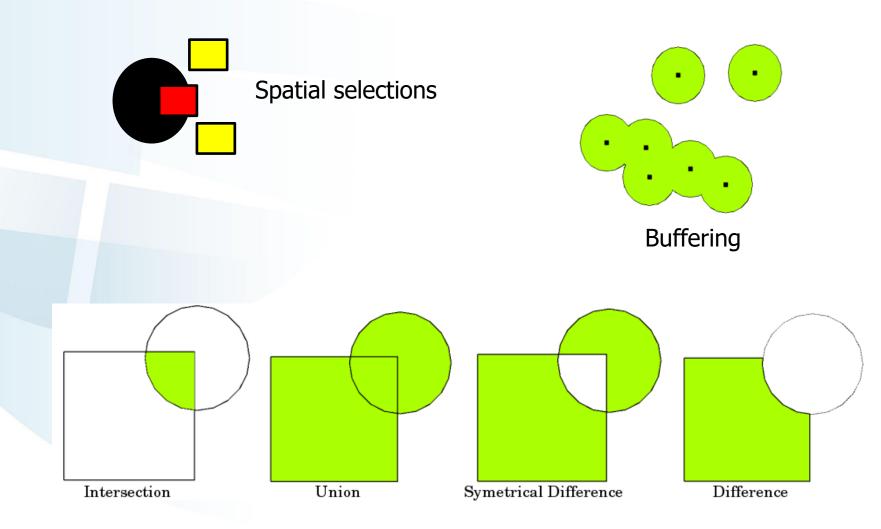
## precision: double (default; no precision model)

## First 3 features:

" "			1 Ca ca						
##		BIR74	SID74	NWBIR74	BIR79	SID79	1	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 fea	/ L feature Simp		Simple feature geometry (sfg)



# Spatial analyses – vector data





Source: QGIS documentation

# Spatial analyses – raster data

#### **Examples**

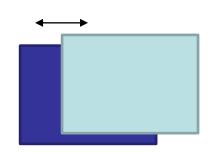
- Aggregations, disaggregations
- Region growth, reclassifications
- Band arithmetic (NDVI etc)
- Terrain analyses (Slope, Aspect, Curvature)

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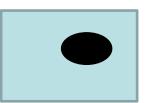


## Common spatial tasks I do in R

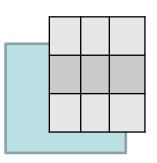
Aligning raster input data



Extracting zonal statistics

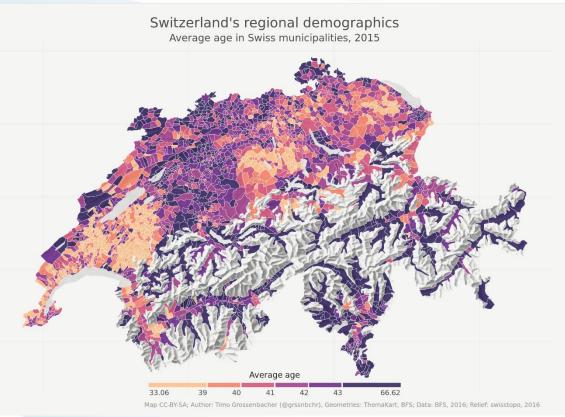


Joining spatial and non-spatial data

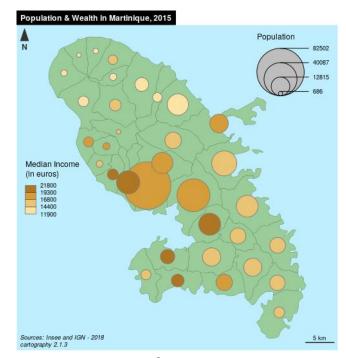




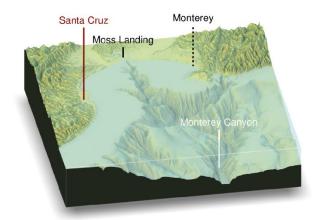
# Making maps in R



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



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



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

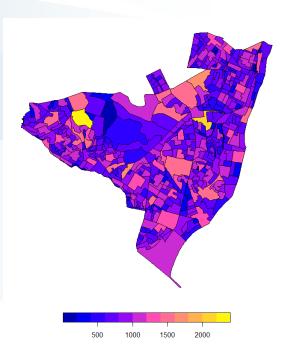


### Spatial statistics

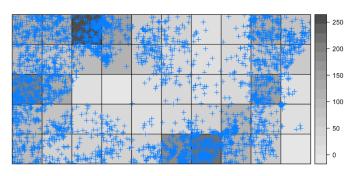
(Not covered in the online course!)

### Geographically weighted Regressions, Kriging, 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.

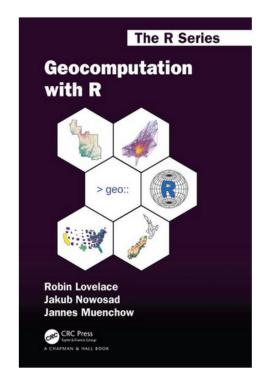
**Note**: This book has now been published by CRC Press in the R Series. You can buy the book from CRC Press, Wordery, or Amazon.

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.





#### Online course materials

Spatial data and analysis in R

Starting page

Lecture Installing packages

Contents -

Resources

Code ▼

#### Spatial data and analysis in R

#### Martin Jung

Ecosystems Services and Management

International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

Apart from the lecture slides this online self-learning course aims to provide you with basic knowledge about spatial datasets in R, how to load and analyse them. In many instances R might not be the fastest tool one can use for these kinds of analyses, but it certainly is the fastest in terms of time spent in code development. Here we will use R as a wrapper to load in external tools. This course assumes that users already have basic knowledge of R.

I generally tried to avoid replicating things that are already openly available online through other resources. Thus, if you are interested in more or other training materials regarding spatial data and analyses in R, check out the resources link at the top with more examples and free self-learning tutorials.







Thank you for your attention.

Good success with your spatial data!

