Lecture 02: Geospatial Data Sciences and Economic Spatial Models

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14-15/Jan/2026

Geospatial Data and Spatial Models: Schedule

1. ~~Introduction to (spatial) data and programming in `R`~~ **[08/Jan/2026]**

2. Week 2-4: Vector spatial data **[14 - 29/Jan/2026]**

    - Week 2: Introduction and basics of vector data using `sf`
    - Week 3: Vector data operations: attribute- and spatial-based
    - Week 4: Geometry-based operations (or transformations)

3. Week 5-7: Raster spatial data + (basic) interactive tools **[05 - 19/Feb/2026]**

4. Week 8-10: Spatial models and applications with data **[25/Feb - 12 Mar/2026]**

5. Take-home exam **[27/Mar/2026]**

Main references for this class

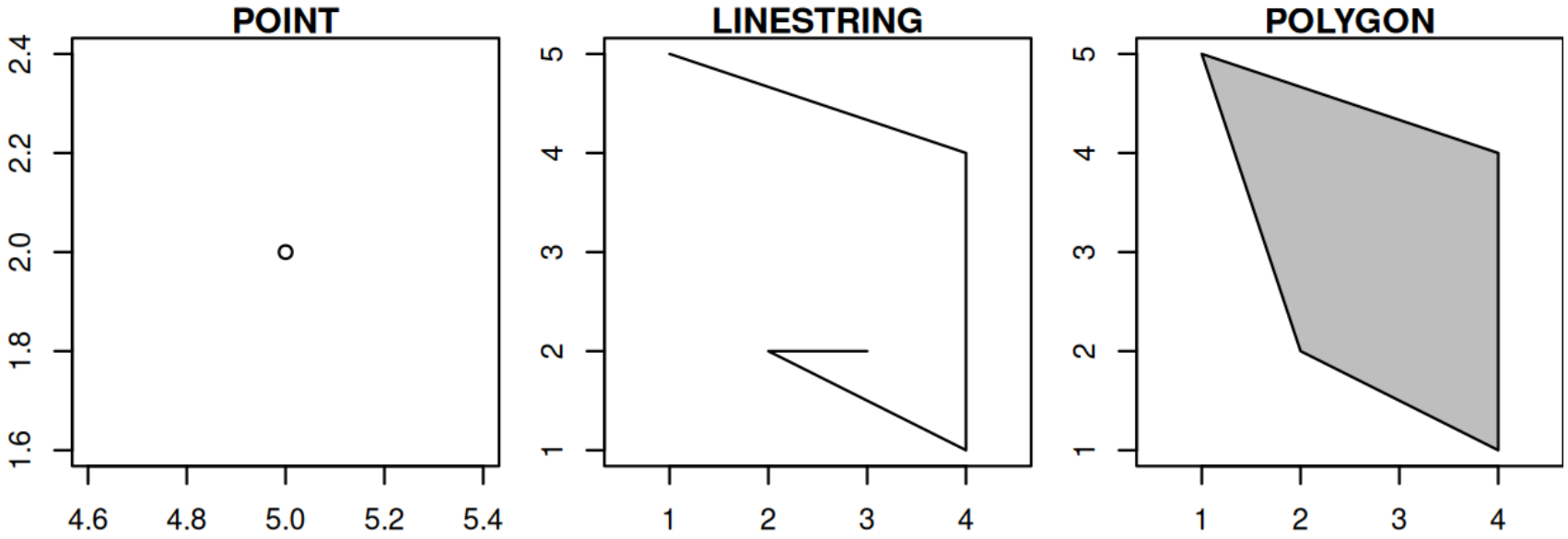
1. Lovelace, R., Nowosad, J. and Muenchow, J., 2019. **Geocomputation with R.** Chapman and Hall/CRC.

2. Pebesma, E., 2018. Simple Features for R: Standardized Support for Spatial Vector Data. The R Journal 10 (1), 439-446

3. Wickham, H. and Grolemund, G., 2016. R for data science: import, tidy, transform, visualize, and model data. " O'Reilly Media, Inc.".

Spatial data types: vector and raster

- GIS systems represent spatial data in either vector or raster formats
  - **Vector data:** spatial geometries as a collection of points over a geography
  - Can represent different objects (points, lines, polygons, multiobjects)



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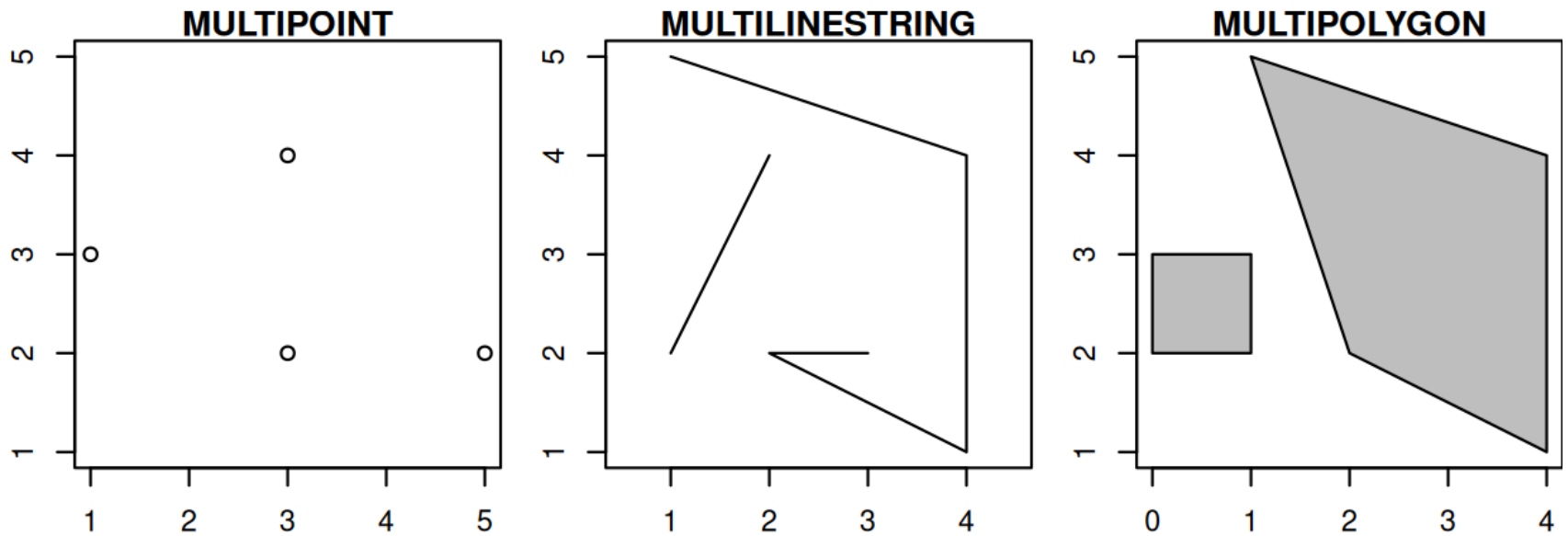


Spatial data types: vector and raster

- GIS systems represent spatial data in either vector or raster formats
  - **Raster data:** geography as continuos of pixels (gridcells) with associated values
  - Normally represents high resolution features of the geography (like an image)

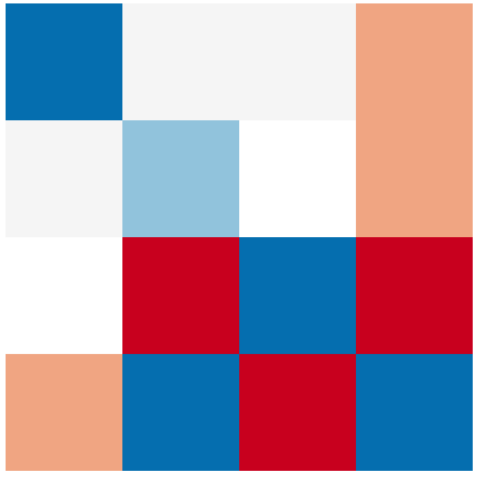
A. Cell IDs

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



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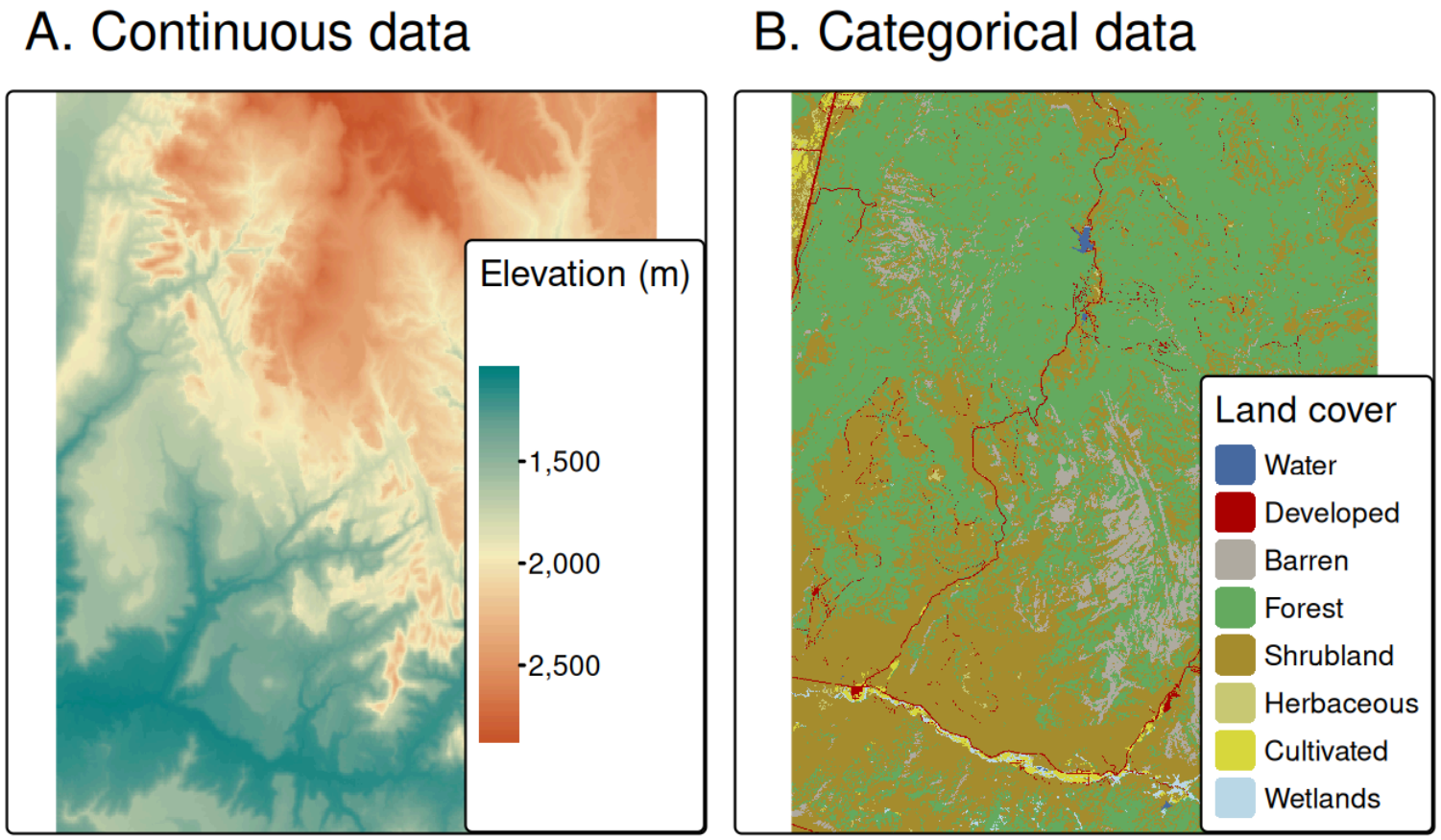


Spatial data files: vector and raster

- **Vector data:** file packages (usually multifiles)
  - Shapefiles (`*.shp`), contains also several auxiliar files (e.g. `*.dbf`, `*.shx`). Most used!
  - GeoJSON (`.json`) is written in Javascript (used mostly in web interfaces)
  - Geopackage (`*.gpk`), unique package/file
  - KMZ (`*.kmz`), from Google Earth format
- **Raster data:** imagery
  - `*.tiff` (most used)
  - Other image files (e.g. `jpeg`, `gif`, `png`)
  - NetCDF files (`*.nc`) standardized data for geoscience (CDF = common data format)

Spatial data: sources

There is almost **infinite** availability of spatial data in the internet. Here is a non-comprehensive list:

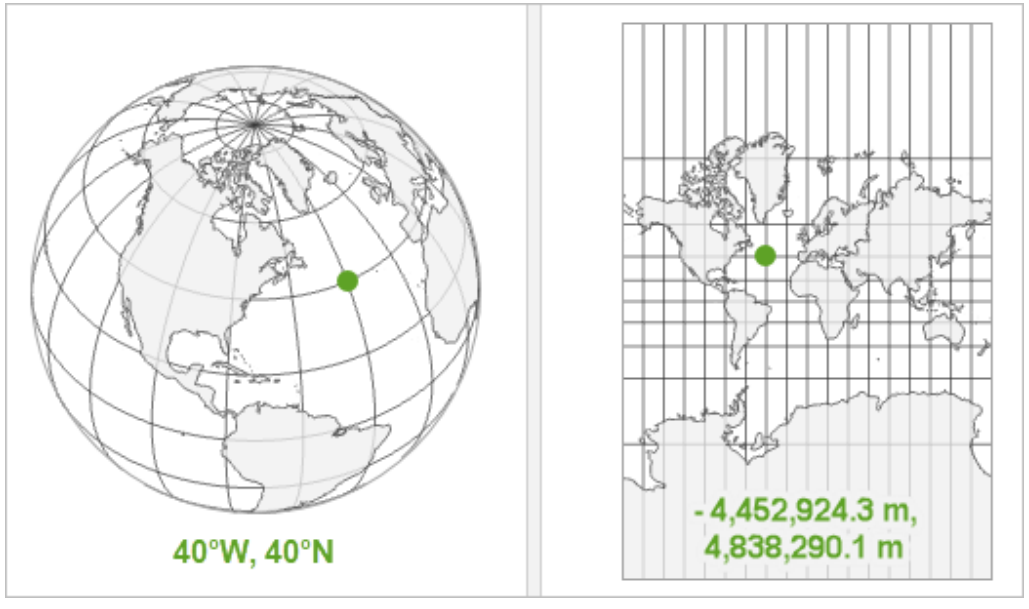
- Natural Earth: immense GIS database
- SAGE: also large GIS databse
- DIVA: nice GIS database by country
- GADM: country boundaries (ADM0-4)
- USGS: satellite imagery
- Modis: satellite imagery
- STRM: elevation
- SAGE: land cover
- GFC: forest change
- gROADS: road networks
- Mineral Resources: location of minerals
- AQUASTAT: water-related data
- FAO-GAEZ: farm/land-related data
- Harvest Choice: farm/land-related data
- mapSPAM: farm/land-related data
- PS Lab: temperature/precipitation
- SPEI: drought index
- LSMS: geocoded surveys
- DHS surveys: geocoded surveys
- Geographic names: to geocode localities
- Long-lat: API to geocode by names
- NOAA VIIS: Satellite Nighttime lights

Getting started: Vector data and the Simple Features in R

Vector data and geographical projections

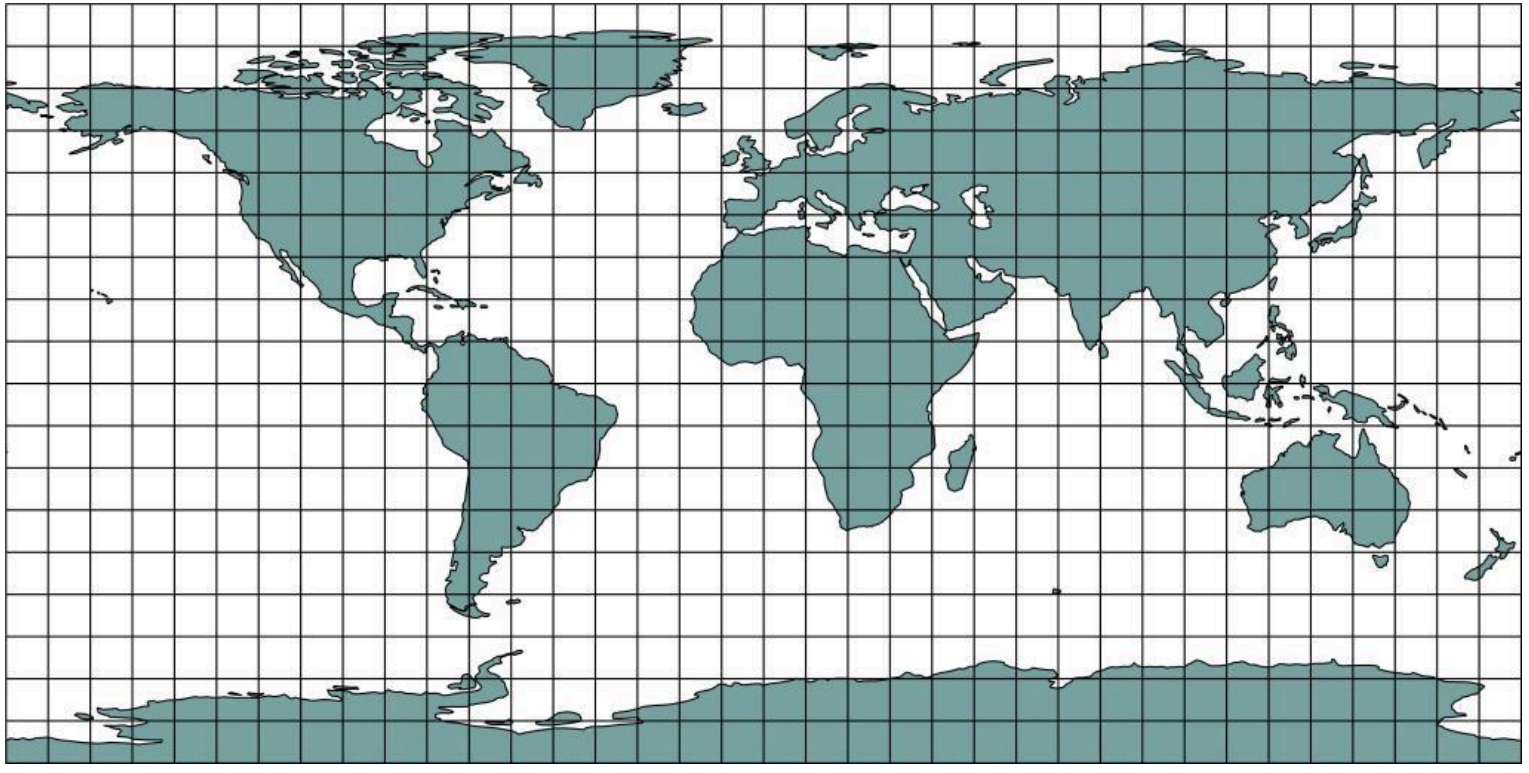
- **Vector:** collection of points over a geography (longitude-latitude; i.e. X-Y)
- X-Y geographical axis: change depending on the geographical projection
- Same geometry can be represented by different combination of X-Y points
- Important takeaways:

    1. Know the data's projection system
    2. Standardize them in you applications



Vector data and geographical projections

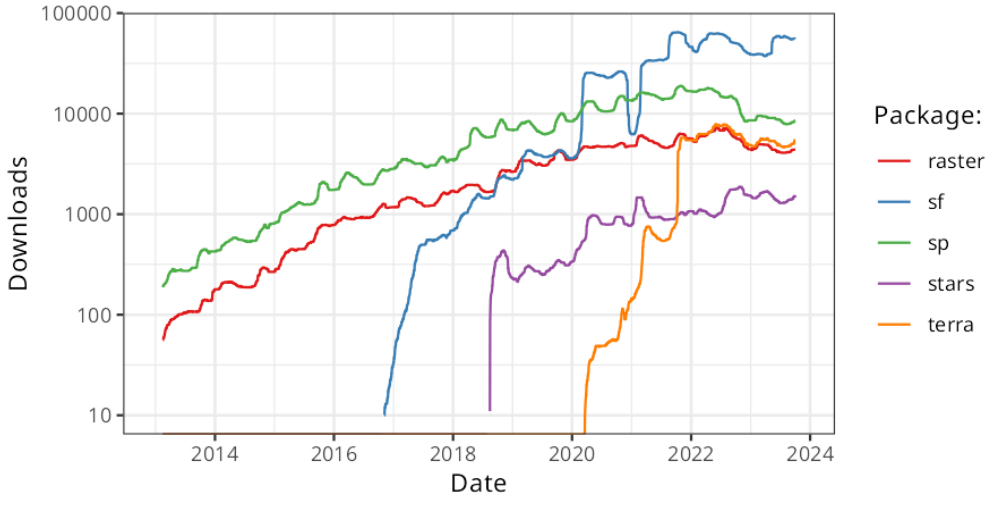
- **Most usual is WGS 84:** longitude (-180,180), latitude (-90,90); CRS code EPSG:4326
- CRS = Coordinate Reference System (synonym to geographical projection)



Vector data in R: the simple features package

- Spatial data in R: a Simple Feature (the `sf` library)
- State-of-art, standardized set of functions for GIS tasks
- Replace "old" libraries (e.g. `sp`, `rgdal`)
- Revolution on GIS in R (`#RSpatial`)
  - Interacts with `dplyr` "pipe" syntax
  - Computational- and memory-efficiency gains

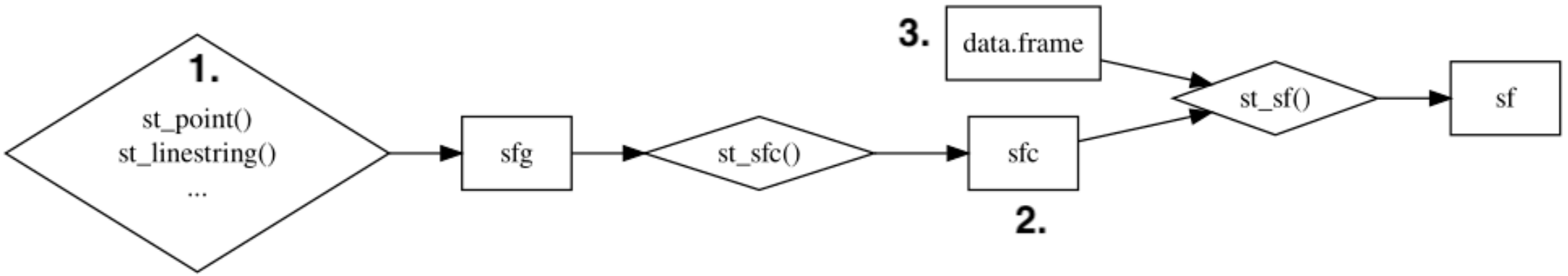
Downloads of `R` libraries:



Vector data in R: the simple features package

- **Core elements of a Simple Feature:**

  1. Geometry (point, lines, polygons): a collection of points (`sfg`, simple feature geometry)
  2. Projection: a CRS parameter that places the points over the world's geography (`sfc`, simple feature column)
  3. Attributes: data associated with each feature/observation (1+2+3 = `sf`: simple feature)



Vector data in R: the simple features package

- Representation of a Simple Feature in R console

```
## Simple feature collection with 4 features and 3 fields
## Geometry type: POINT
## Dimension:     XY
## Bounding box:  xmin: -3.7 ymin: 40.4 xmax: 11.3 ymax: 51.5
## Geodetic CRS:  WGS 84
##      name temperature language           geometry
## 1 Bologna          31  Italian POINT (11.3 44.4)
## 2  London          21  English POINT (-0.1 51.5)
## 3  Madrid          29  Spanish POINT (-3.7 40.4)
## 4   Paris          28   French  POINT (2.3 48.8)
```

Vector data in R: creating simple features

1. Creating geometries:
    - Points: `st_point()` with a x-y **vector**
    - Lines: `st_linestring()` with a **matrix** of all x-y coordinates (columns) of each line vertex (rows)
    - Polygons: `st_polygon()` with a **list** containing a matrix of all x-y coordinates of each polygon vertex (first and last must be the same!)
2. Adding projection: `st_sfc(geometry,crs)`
    - Adds the `crs` projection to the `st_*()` geometry
    - WGS 84: use `crs = 'EPSG:4326'`
3. Creating a simple feature: `st_sf(data.attributes,geometry = sfc)`

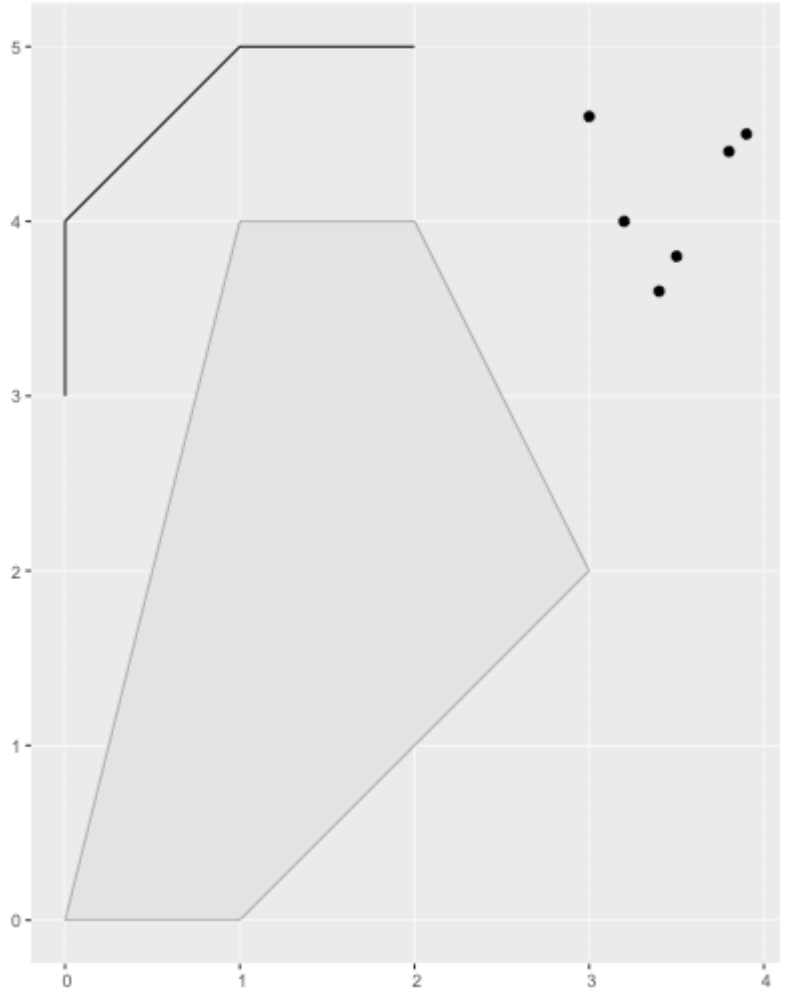
Vector data with Simple Features: attribute data operations

Vector data operations

- **Operations of spatial features** (i.e. manipulation): by attribute or geometry (spatial)
  - Attribute opperations: disciplined by the underlying attributes (feature's dataset)
  - Spatial operations: manipulations across the space (i.e. rotating, moving, distances, etc.)
- Attribute data operations:
  - Nested on `dplyr` "pipe" operators/funtions (e.g. filter, slice, etc.)
  - Equivalent to data operations but also accounting for the geometry of the feature
- **Detailed exposition:** on class material `01_class02.R`

Hands-on: your turn! (1/2)

- Creating artificial spatial data with `sf`
- Generate the following features:
  - `MULTIPOINT ((3.2 4), (3 4.6), (3.8 4.4), (3.5 3.8), (3.4 3.6), (3.9 4.5))`
  - `LINESTRING (0 3, 0 4, 1 5, 2 5)`
  - `POLYGON ((0 0, 1 0, 3 2, 2 4, 1 4, 0 0))`
- Plot them together with `ggplot()`



Hands-on: your turn! (2/2)

- **Map of world airports:** download the shapefile of airports in the world from Natural Earth (large scale data). Differentiate airport types by color