

SPATIAL OBJECTS IN R USING R AS A GIS SOFTWARE

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Section for Ecoinformatics & Biodiversity

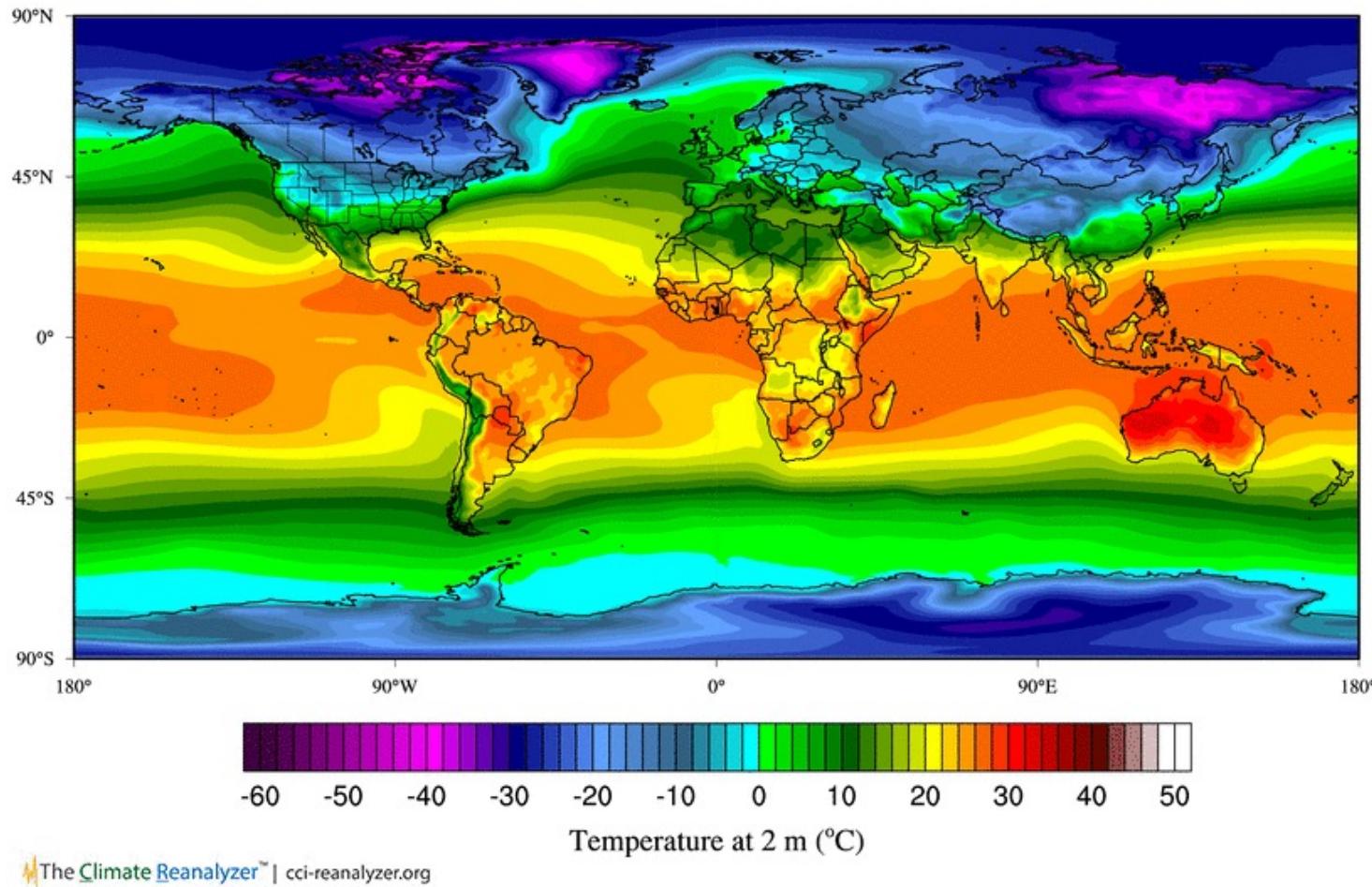
Center for Biodiversity Dynamics in a Changing World (BIOCHANGE)

SPATIAL OBJECTS IN R

WHAT WE WILL TALK ABOUT TODAY

- R as a GIS tool.
- Spatial object classes – Point, lines, polygons and grids.
- Plotting spatial objects – Plotting Spatial* objects.
- Spatial Raster's in R – From features to gridded information.
- Operations with Rasters – Map algebra with Raster* objects.
- Linking to other GIS Software – How to load/save info coming from other programs.

**Any questions?
Ready to begin?**



The Climate Reanalyzer™ | cci-reanalyzer.org

We live in a data-rich world... and most of this information is spatiotemporal in nature.



WHAT IS SPATIAL INFORMATION?

Mathematical construct for representing objects or surfaces in the physical world as data.

For this, we need to define:

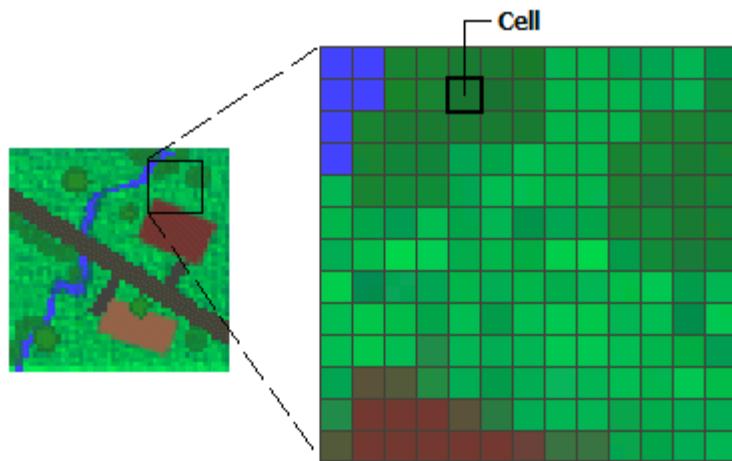
- The Physical **location** of objects
 - Where they are in Earth
 - Linked to a coordinate/projection system.
- The **relation** between objects.
 - How the different elements of the object are placed relative to each other.
- The **attributes** of the objects.
 - The data to be represented

WHAT IS SPATIAL INFORMATION?

Data model types:

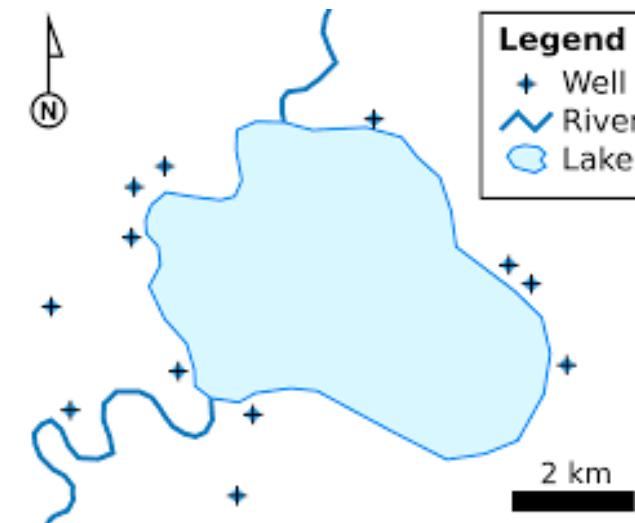
Spatial Raster models:

represents the geography of cell matrices that store numeric values.



Spatial Vector models:

represents geography as collections of points, lines, or polygons.



SPATIAL INFORMATION

WHY R?

STATE OF THE ART

Large availability of basic and of advanced geospatial analytical techniques.

VISUALIZATION

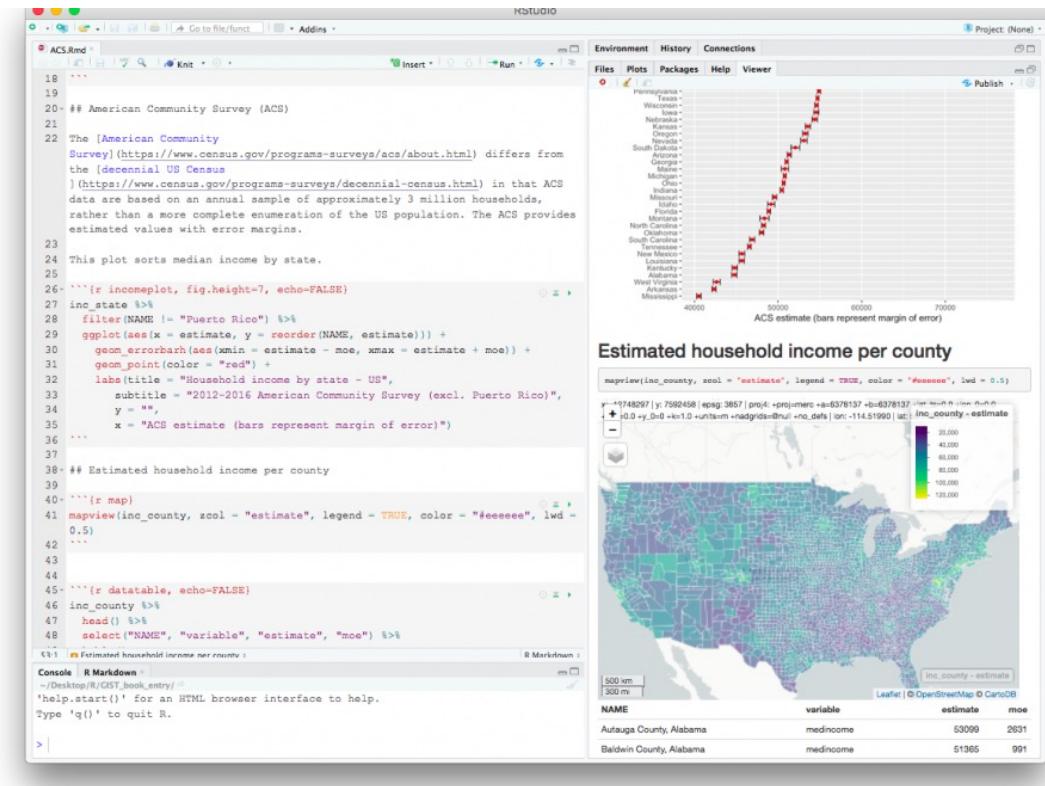
All types of visualizations are easily produced.

INTEGRATION

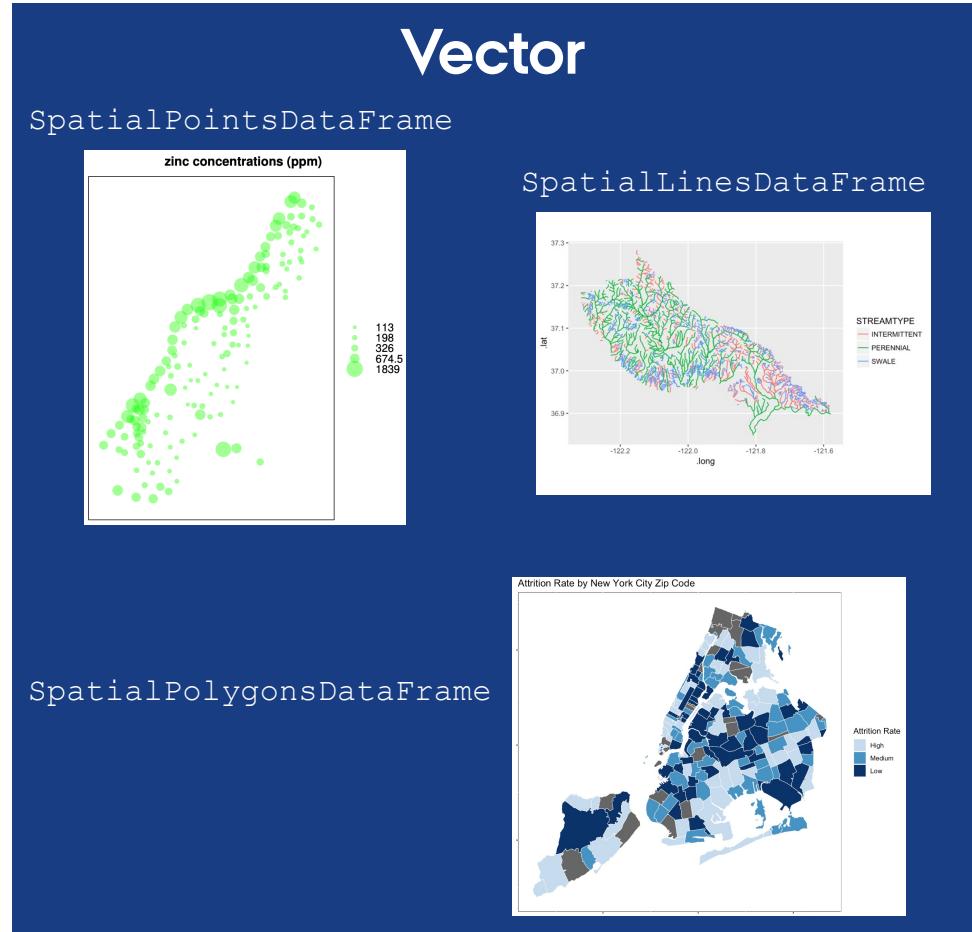
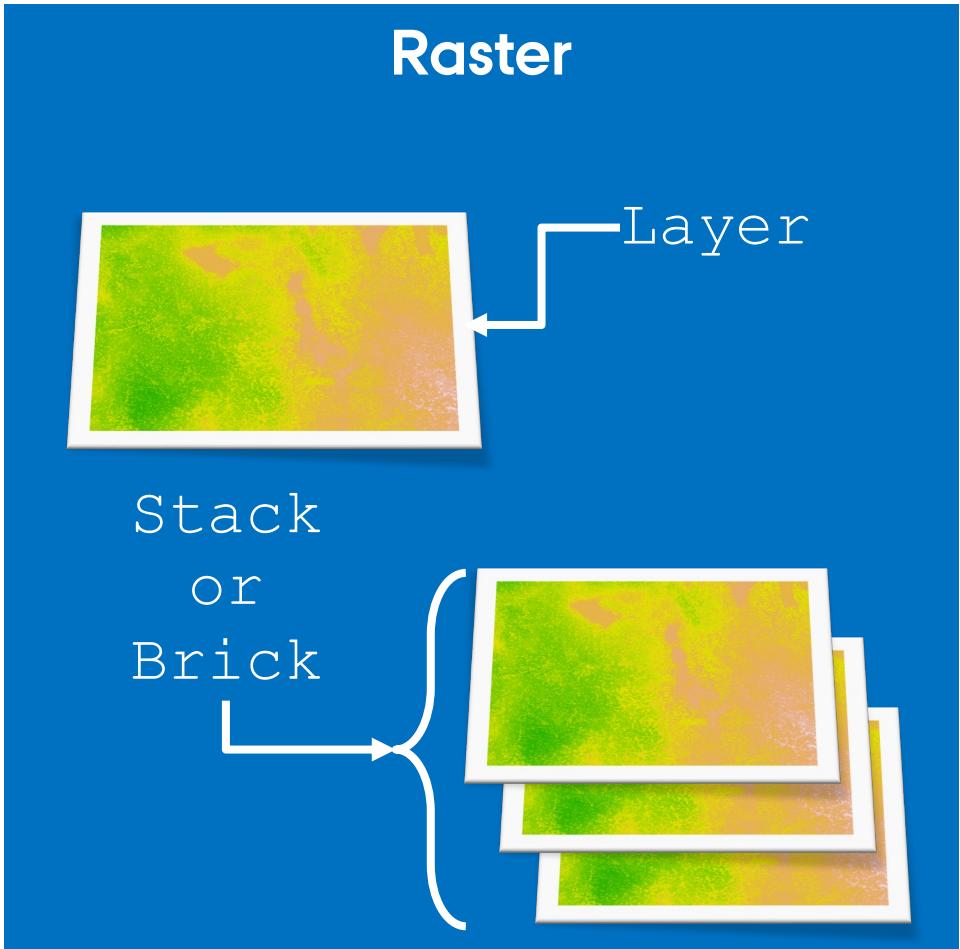
ALL the research pathway is in one single Open-access environment.

REPRODUCIBILITY

What that means is that it is easy to replicate what you have done!



SPATIAL OBJECTS IN R



SPATIAL OBJECTS IN R

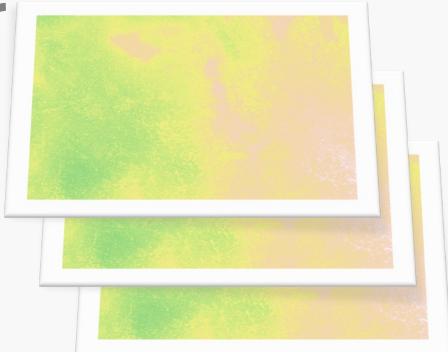
Raster



Layer

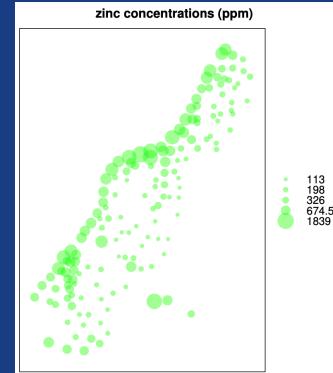
Stack

or
Brick

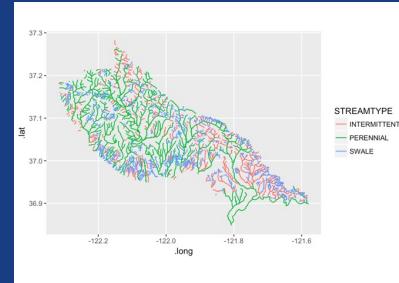


Vector

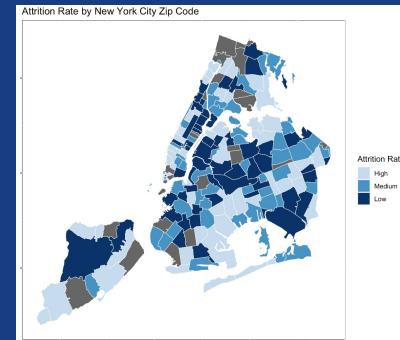
SpatialPointsDataFrame



SpatialLinesDataFrame



SpatialPolygonsDataFrame



SPATIAL*DATABASES OBJECTS IN R

Geometry

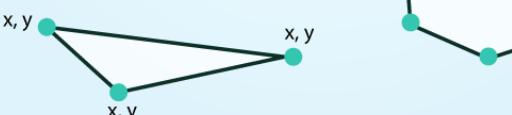
POINTS: Individual **x, y** locations.
ex: Center point of plot locations, tower locations, sampling locations.



LINES: Composed of many (at least 2) vertices, or points, that are connected.
ex: Roads and streams.



POLYGONS: 3 or more vertices that are connected and **closed**.
ex: Building boundaries and lakes.



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Data

ID	Class	Type	Size
1	Forest	Conifer	55
2	Forest	Evergreen	40
3	Herbaceous	Grassland	10
4	Herbaceous	Pasture	20



WHAT IS IN THE “GEOMETRY” PART?

Bounding box



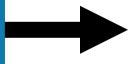
Defines the limits of the “Physical” location of objects.

Coordinate system



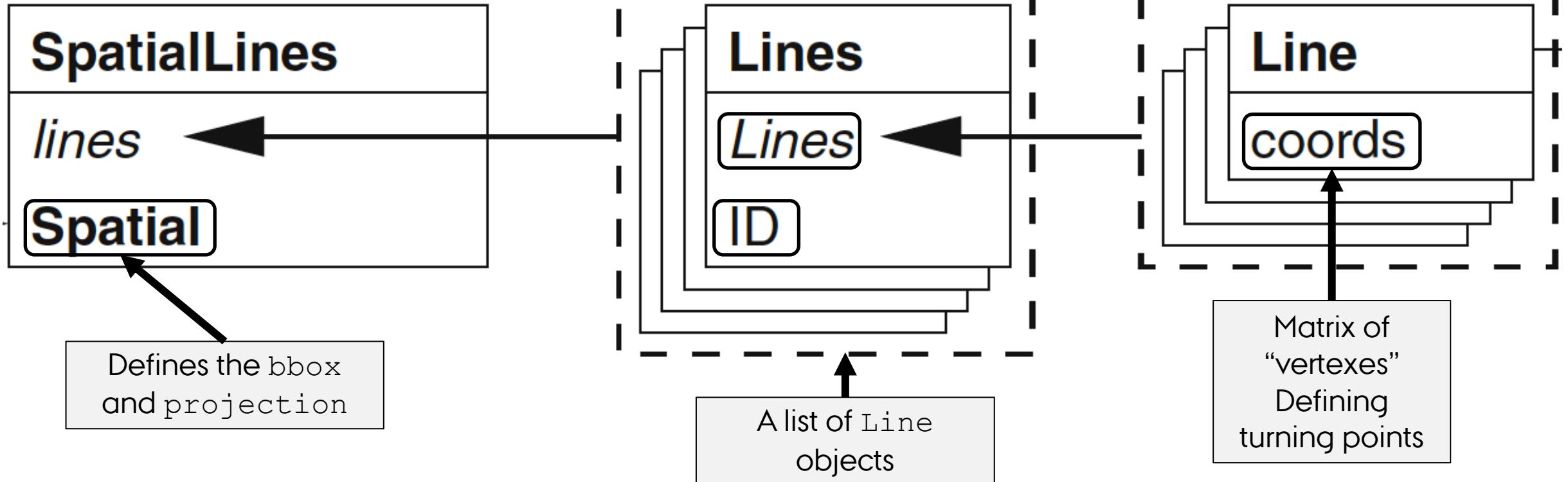
Establishes the framework used to define the location of objects on the surface of the Earth.

Vertex

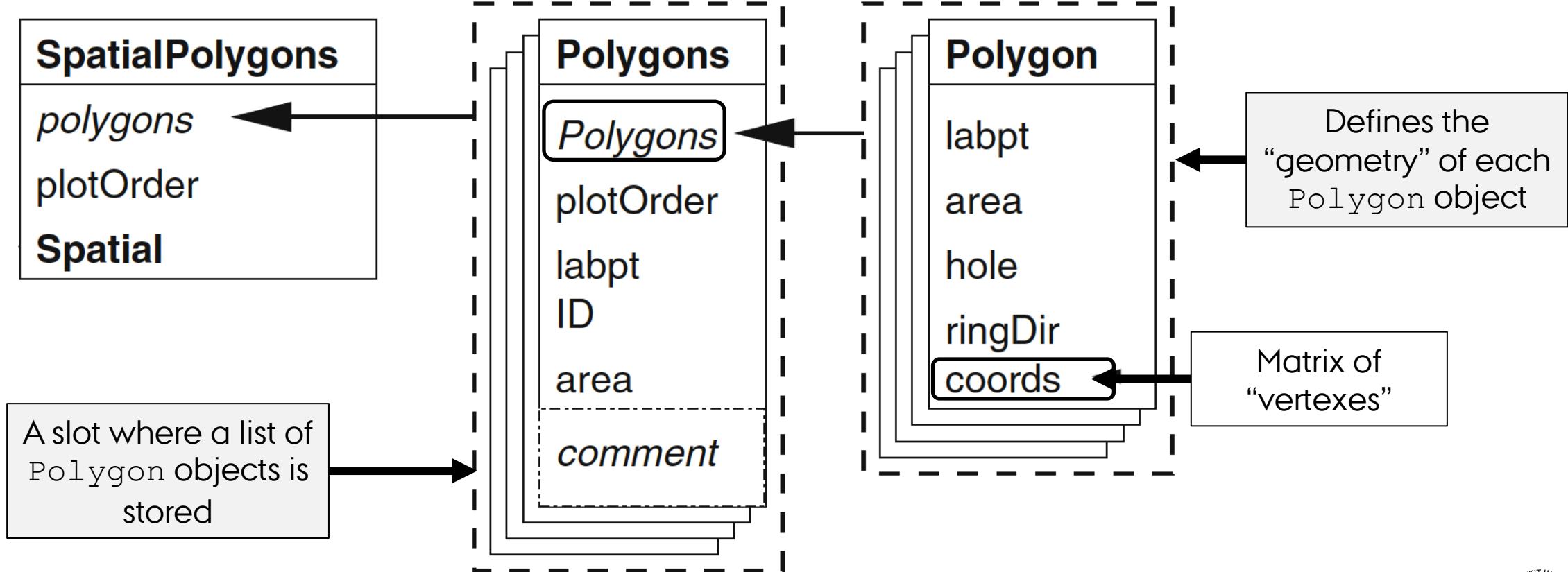


Determines observation locations or the corners/intersections of geometric shapes (lines polygons)

SPATIAL LINES ARE COMBINATIONS OF LINE OBJECTS



SPATIAL POLYGONS ARE COMBINATIONS OF POLYGON OBJECTS



PROJECTIONS IN R CRS CLASS OBJECTS

CRS objects are a character string in the PROJ-format [formerly PROJ.4] that describes the coordinate systems and transformations.

Geographical reference system (GRS)

A spherical representation of the Earth.

Reference framework that defines the locations of features on a model of the earth. It's shaped like a globe—spherical.

Its units are angular, usually **degrees**.

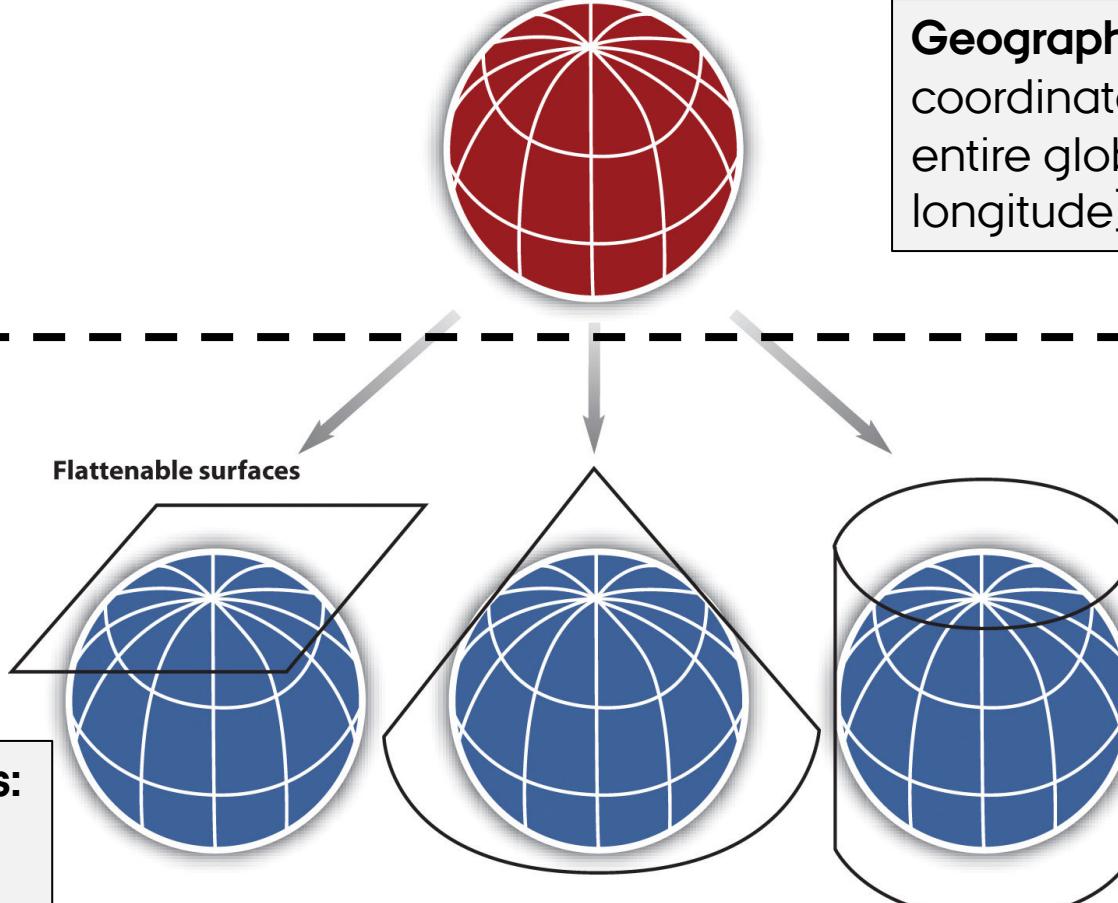
Projected reference system (PRS)

A flat representation of the Earth.

It contains a GRS, but it converts into a flat surface, using math (the projection algorithm) and other parameters.

Its units are linear, most commonly in **meters**.

Geographic coordinate systems: coordinate systems that span the entire globe (e.g. latitude / longitude).



Projected coordinate systems: coordinate systems that are localized to minimize visual distortion in a particular region.

Projections

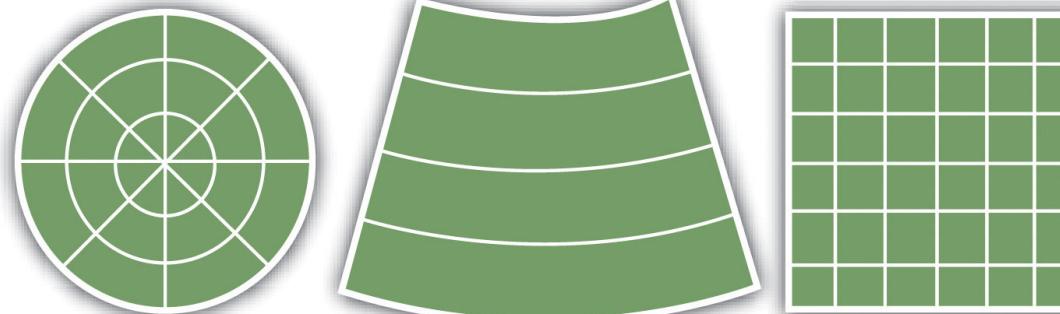
Planar

Conical

Cylindrical

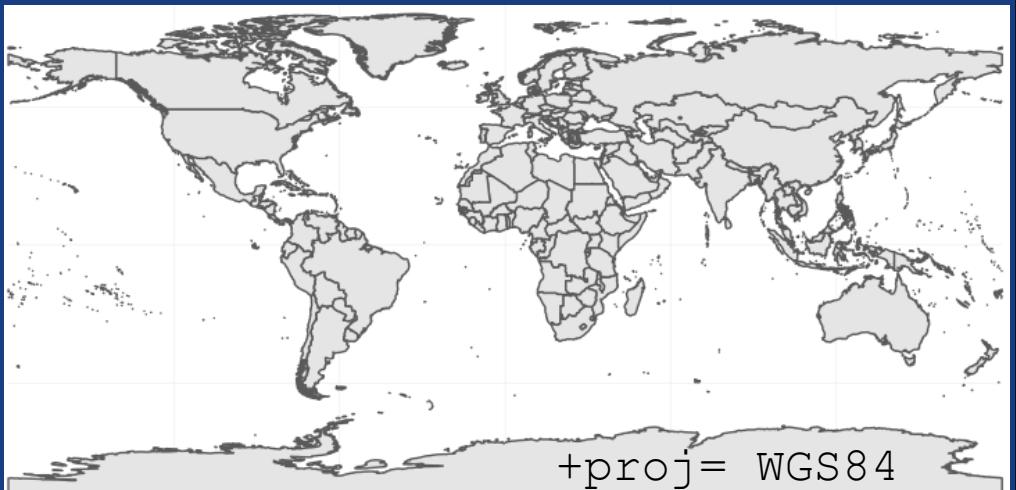
Flat maps

Representations

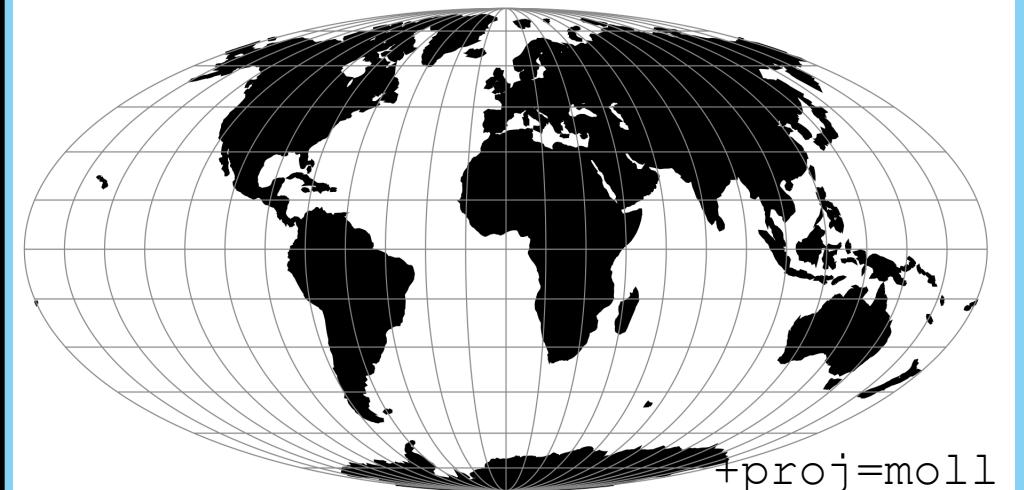


PROJECTIONS IN R CRS CLASS OBJECTS

Geographical reference system.



Projected reference system.



Home -- Spatial Reference x +

spatialreference.org

Spatial Reference welcome

Home | Upload Your Own | List user-contributed references | List all references

Search

Find your references in any number of formats!

- See Existing EPSG Codes: [4326](#), [2805](#)
- [Upload your own Projection as WKT, proj4, etc.](#)
- Browse a list:
 - 4362 EPSG references
 - 447 ESRI references
 - 2380 IAU2000 references
 - 2717 [spatialreference.org](#) references

Recently Viewed

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- [Tokyo / Japan Plane Rectangular CS XI](#), 2673 views, 0 comments
- [Belinda Equidistant Cylindrical](#), 811 views, 0 comments
- [test](#), 954 views, 0 comments
- [LKS94 \(ETRS89\) \(geocentric\)](#), 3521 views, 0 comments

Last update: 2013

Recent Uploads

- SR-ORG:9221: [Pakistan1](#)
- SR-ORG:9220: [BINHHTUAN](#)
- SR-ORG:9219: [Test Projection Arizona Custom](#)
- SR-ORG:9218: [a](#)
- SR-ORG:9217: [ETRS89 / SSBKP](#)

In both these sites you can get the PROJ strings for a defined Projection

Projections — PROJ 7.1.1 documentation

proj.org/operations/projections/index.html

Coordinate operations » Projections

Previous Next

Projections

Projections are coordinate operations that are technically conversions but since projections are so fundamental to PROJ we differentiate them from conversions.

Projections map the spherical 3D space to a flat 2D space.

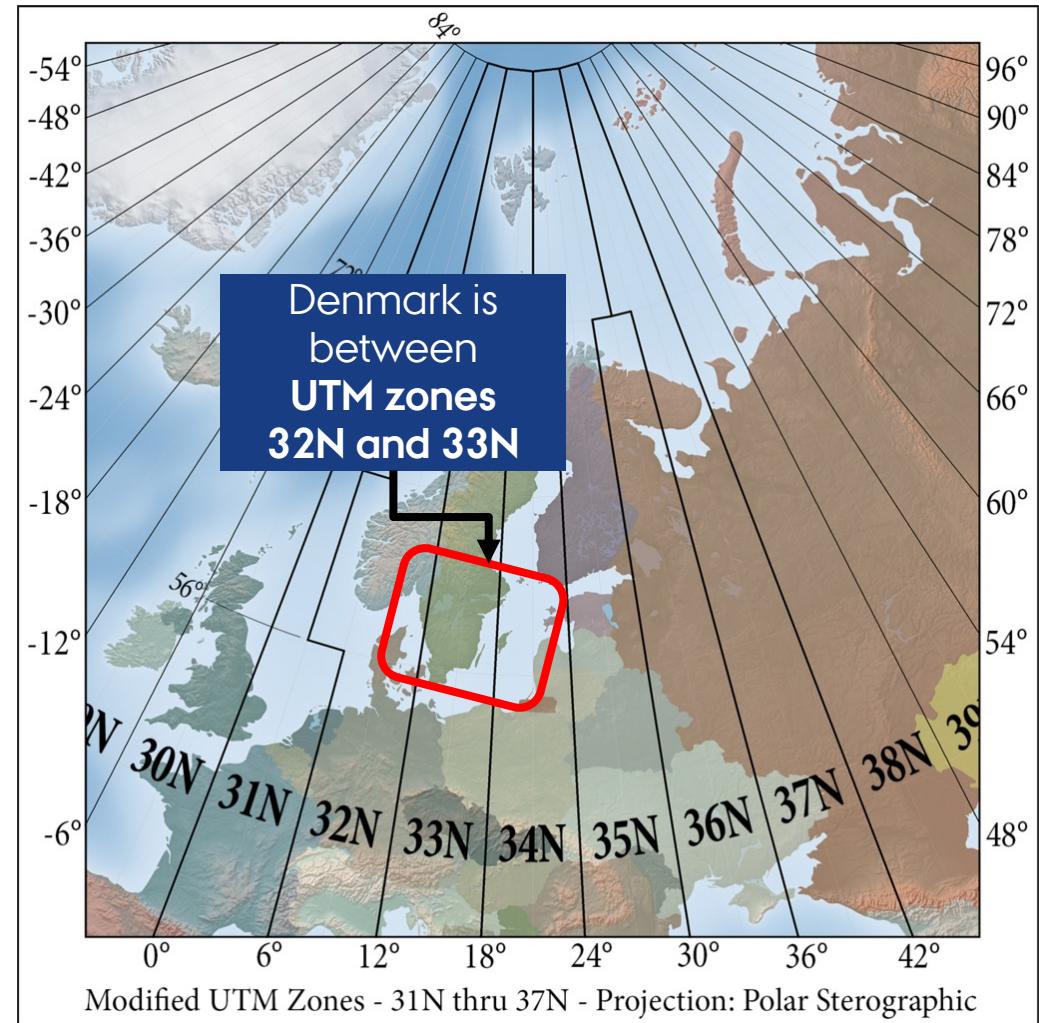
- [Adams Hemisphere in a Square](#)
- [Adams World in a Square I](#)
- [Adams World in a Square II](#)
- [Albers Equal Area](#)
- [Azimuthal Equidistant](#)
- [Airy](#)
- [Aitoff](#)

THE UTM SYSTEM

Universal Transverse Mercator (UTM) projection system is useful to define projections in smaller areas
– like in a country

Provides a constant distance relationship anywhere on the map.

Denmark primary projection is UTM/ETRS89



Check <https://sdfe.dk/media/2917583/001-etrs89-utm.pdf> for the official projection of Denmark.
And <https://epsg.io/25832> for the proj string

WHAT IS IN THE “DATA” PART?

Example Attributes for Point Data

ID	Plot Size	Type	VegClass
1	40	Vegetation	Conifer
2	20	Vegetation	Deciduous
3	40	Vegetation	Conifer

Example Attributes for Line Data

ID	Type	Status	Maintenance
1	Road	Open	Year Round
2	Dirt Trail	Open	Summer
3	Road	Closed	Year Round

Example Attributes for Polygon Data

ID	Type	Class	Status
1	Herbaceous	Grassland	Protected
2	Herbaceous	Pasture	Open
3	Herbaceous / Woody	Grassland	Protected

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SpatialPointsDataFrame
Each **point** is a row

SpatialLinesDataFrame
Each **line** is a row

SpatialPolygonsDataFrame
Each **Polygon** is a row

So far so good?

Any questions?

Ready to continue?

WHAT'S ON TOP OF WHAT?

One of the most basic questions asked of a GIS?

This questions are answered with the use of overlay tools that based on the overlap of multiple feature classes can:

Base operations

Erase

Intersect

Union

Derived operations

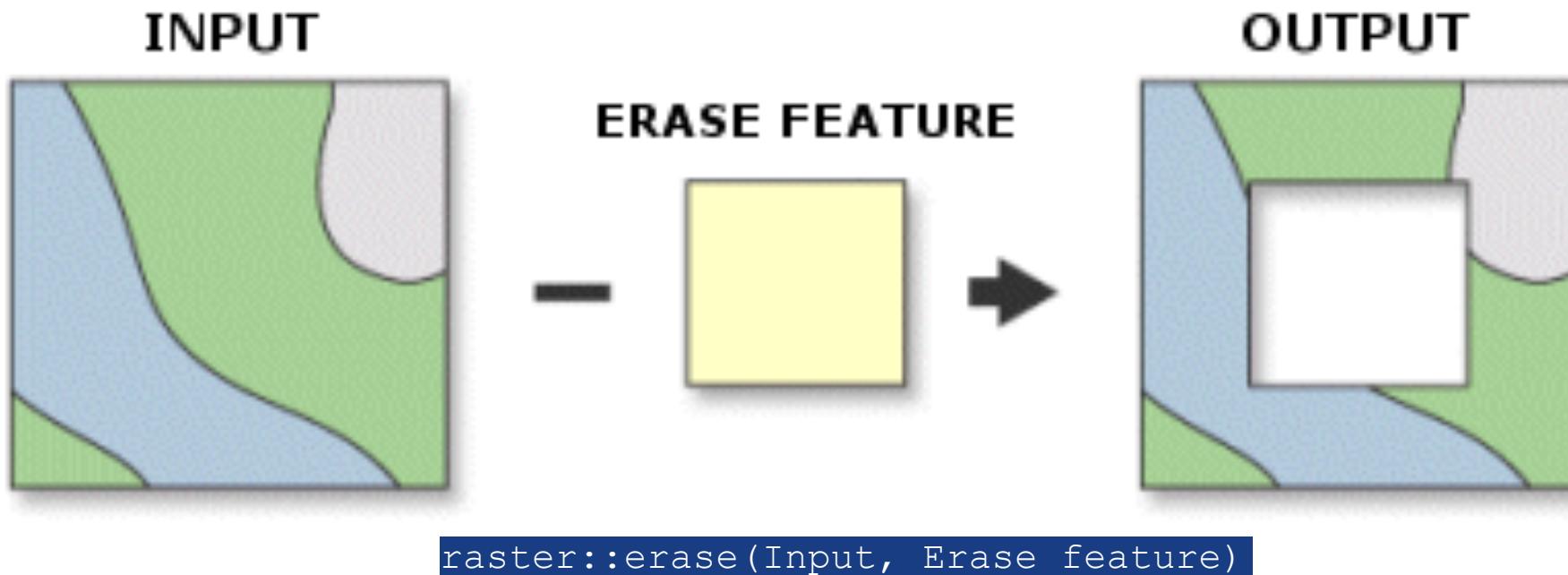
Identify

Difference

ERASE

Creates a feature class by overlaying the **Input Features** with the polygons of the **Erase Features**.

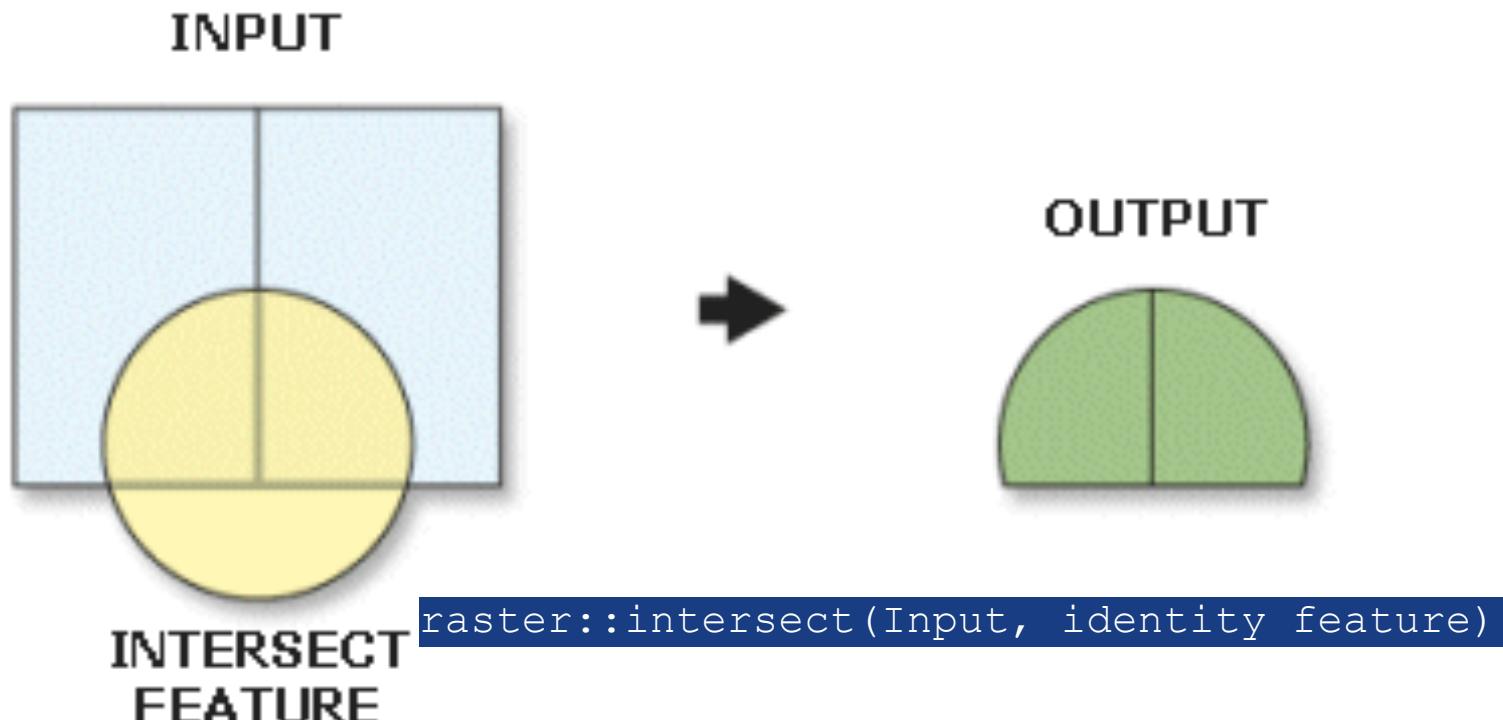
Only those portions of the input features falling outside the erase features outside boundaries are copied to the output feature class.



INTERSECT

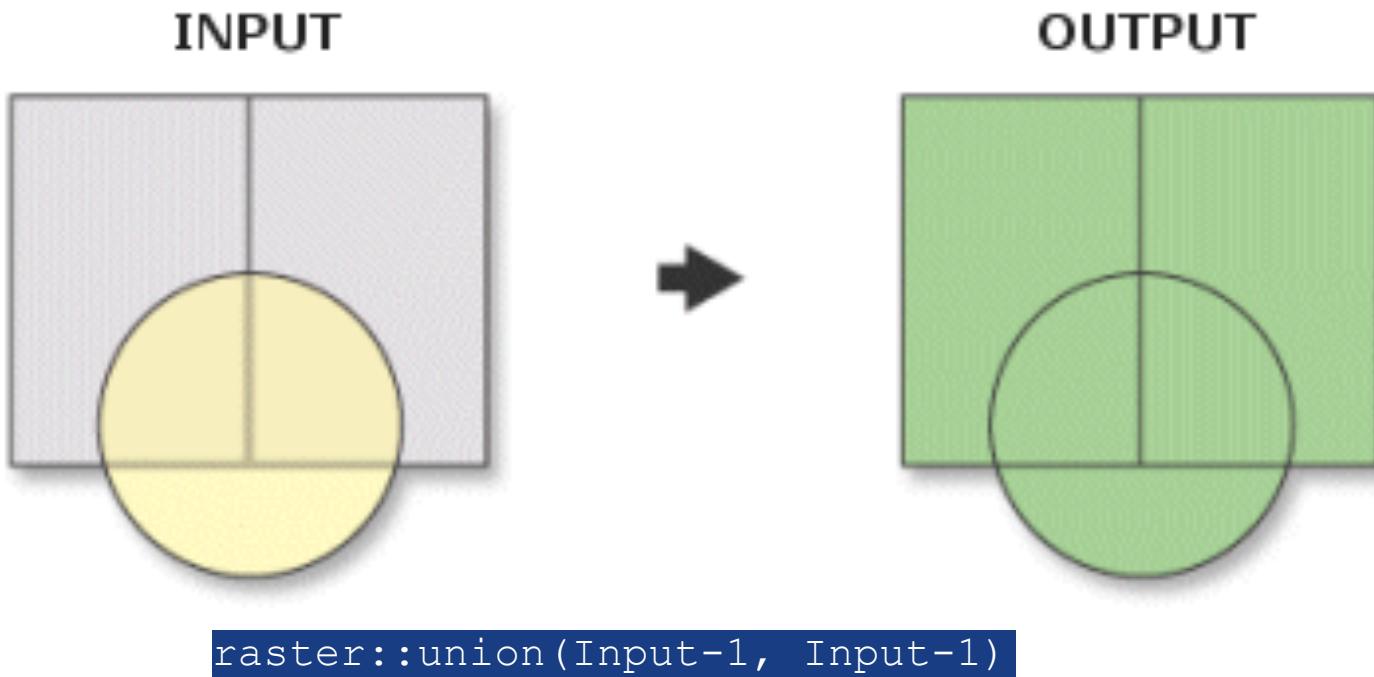
Computes a geometric intersection of the input features.

Features or portions of features which overlap in all layers and/or feature classes will be written to the output feature class.



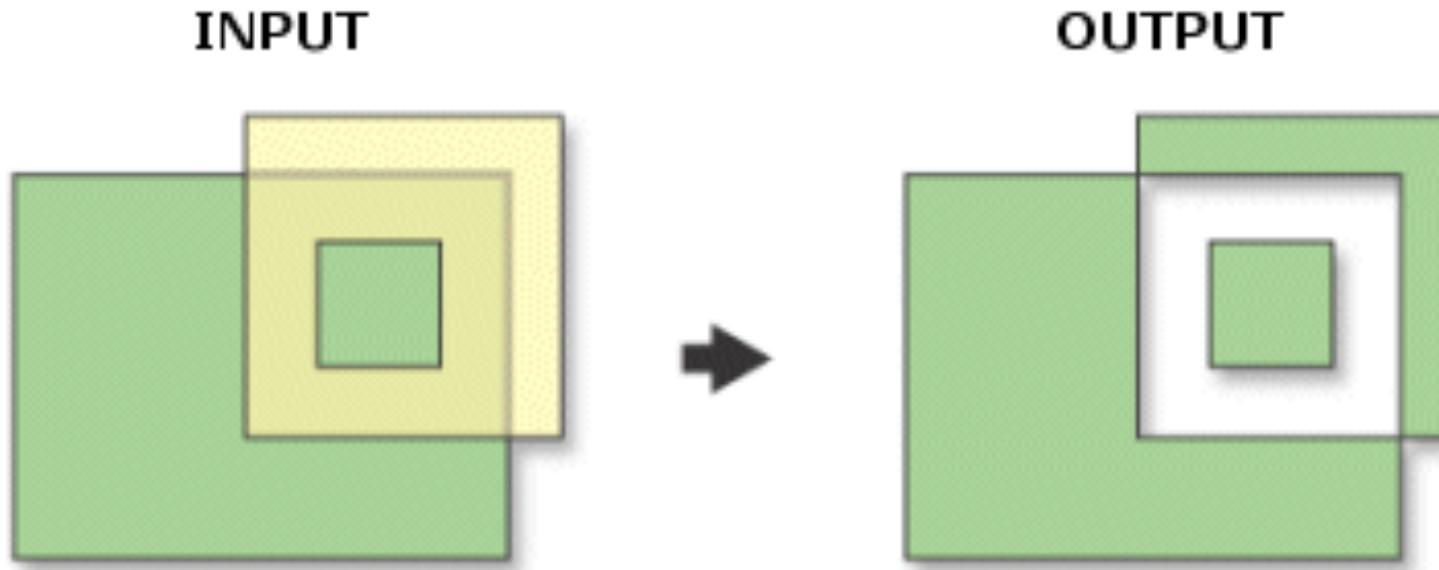
UNION

Computes a geometric union of the input features. All features and their attributes will be written to the output feature class.



DIFFERENCE

Features or portions of features in the input and update features that do not overlap will be written to the output feature class.

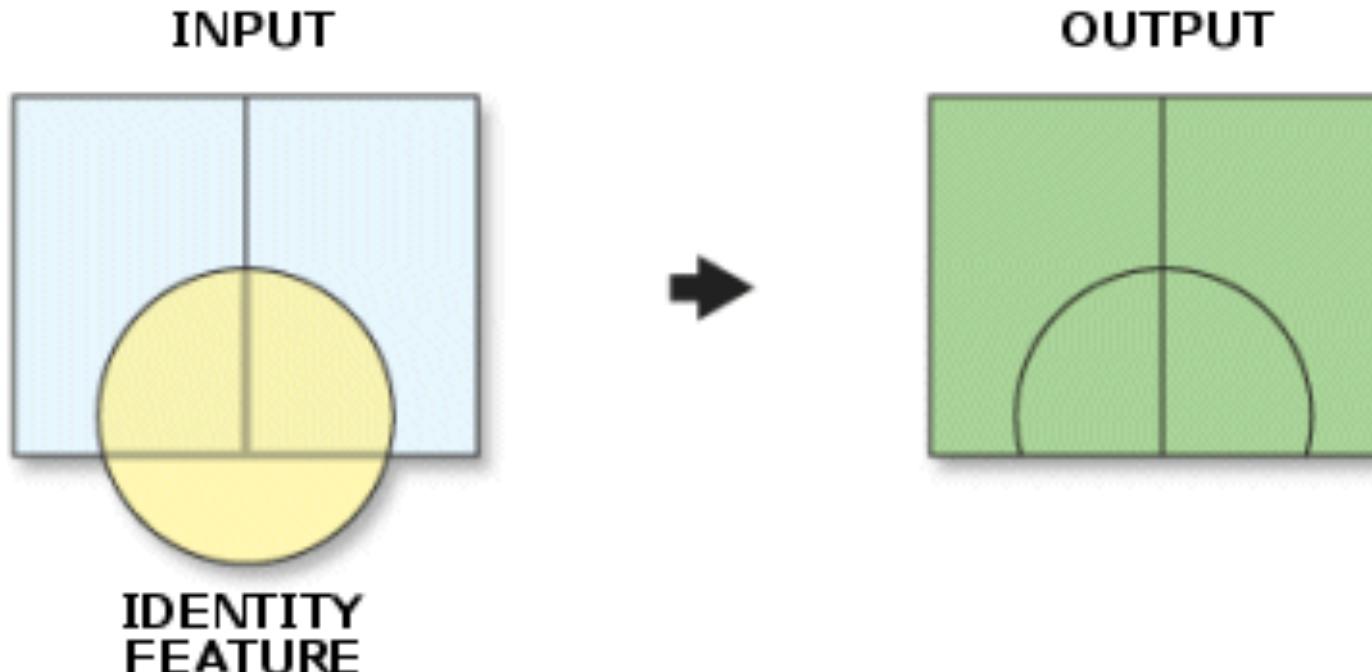


In R this requires a combination of erase and union functions
Step.1 erase yellow from green.
Step.2 erase green from yellow.
Step.3 Union the results of Step 1 and Step 2

IDENTITY

Computes a geometric intersection of the input features and identity features.

The input features or portions thereof that overlap identity features will get the attributes of those identity features.



In R this requires a combination of erase and union functions

Step.1 erase green from yellow.

Step.2 erase step 1 from yellow.

Step.3 Union the results of Step 2 and blue

So far so good?

Any questions?

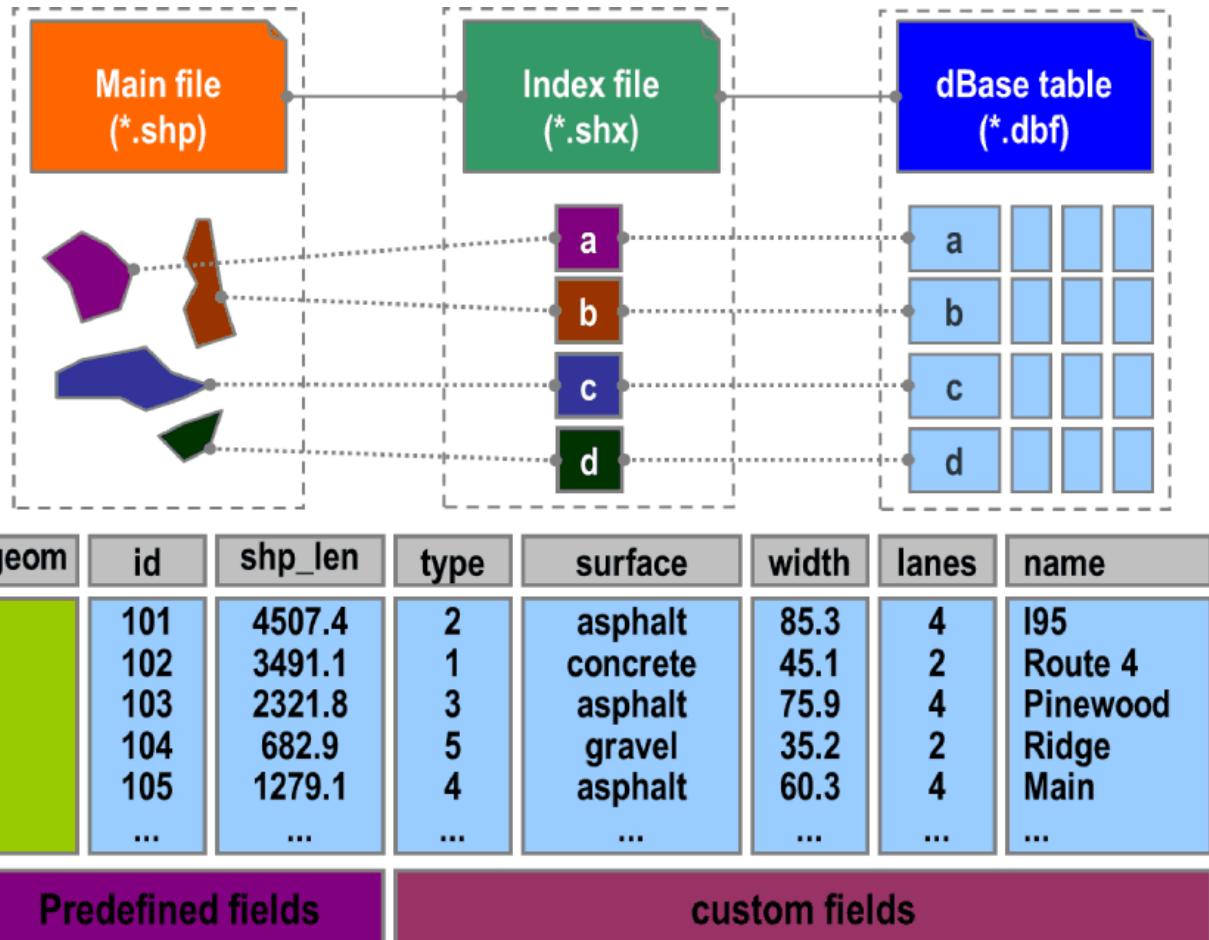
Ready to continue?

GIS VECTOR FILES

A format that is commonly used for exchanging vector data is the ESRI shapefile – represented by three files

- **Main file** of geometries.
- **Index file** to the geometries.
- **dBase** storing attribute data.

You always need the three files!



LOAD GIS VECTOR FILES IN R

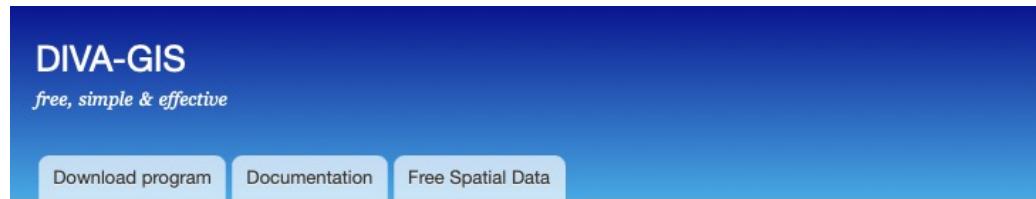
All vector loading functions in R depend on the Geospatial Data Abstraction Library (GDAL).

- You will be able to open and save almost all existing geospatial formats!
- But, you need to have the `rgdal` library installed.



Data type	read	classes from package sp	Basic methods for classes
Vector data 	<code>readOGR()</code>	SpatialPoints SpatialPointsDataFrame SpatialLines SpatialLinesDataFrame SpatialPolygons SpatialPolygonsDataFrame	Get extent: <code>bbox()</code> Get projection: <code>proj4string()</code> Get coordinates: <code>coordinates()</code>

WHERE I CAN FIND SHAPEFILES BASE CARTOGRAPHY



Home

Download data by country

Select and download free geographic (GIS) data for any country in the world

Country

Denmark

Subject

Administrative areas

OK

Sources

Subject	Description	Source	Format	Resolution
Administrative areas (boundaries)	Country outlines and administrative subdivisions for all countries. The level of subdivision varies between countries	GADM, version 1.0	Vector (area)	-
Inland water	Rivers, canals, and lakes. Separate files for line and area features	Digital Chart of the World	Vector (line and area)	-
Roads	Roads	Digital Chart of the World	Vector (line)	-
Railroads	Railroads	Digital Chart of the World	Vector (line)	-

<https://bit.ly/2H9ZZ9d>

WHERE I CAN FIND SHAPEFILES BIOLOGICAL DATA

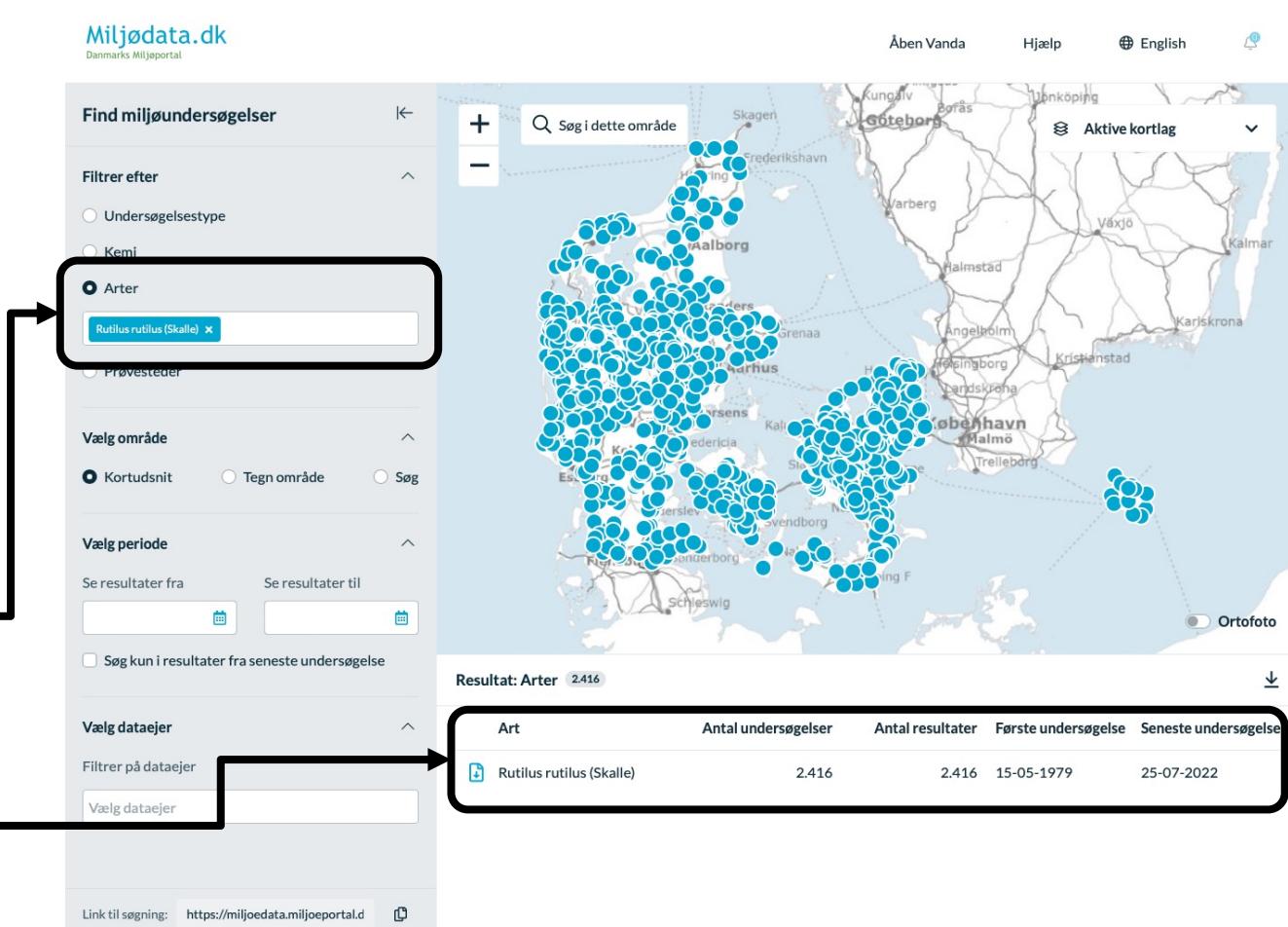
Danmarks Miljøportal
Data om miljøet i Danmark

<https://miljoeportal.dk>

Main data source for Danish
biological Data.

1. Specify the
species

2. Download
the records

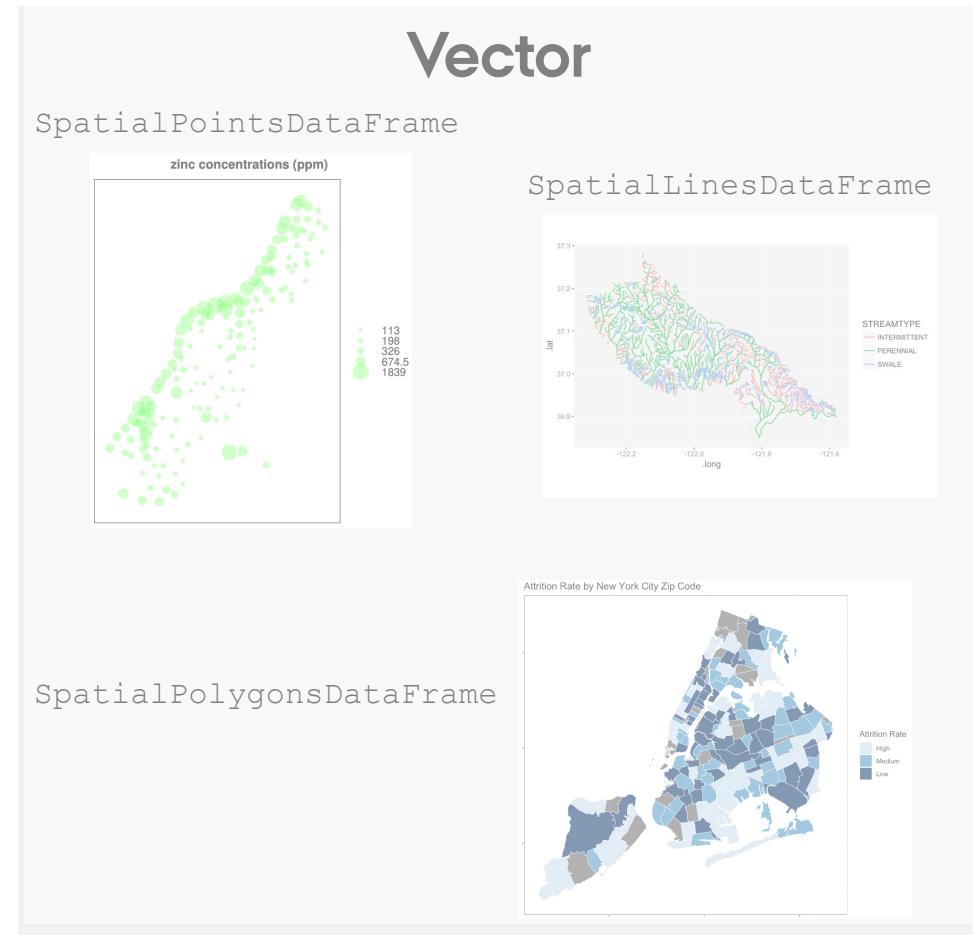
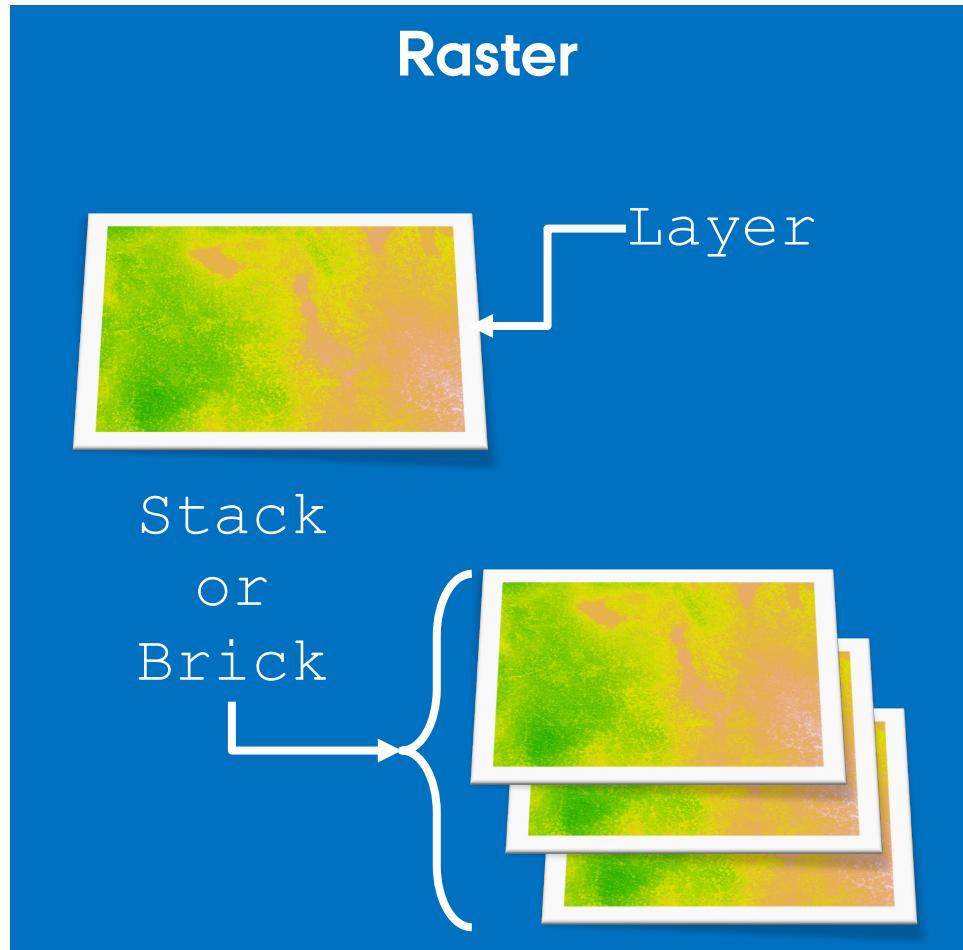


So far so good?

Any questions?

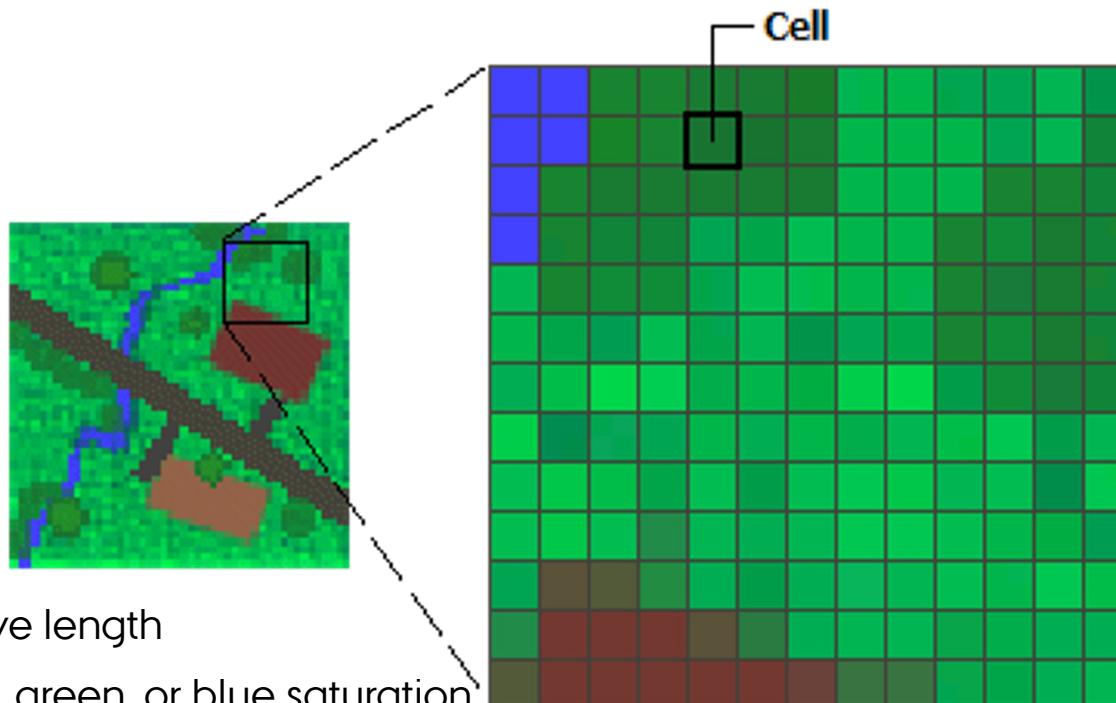
Ready to continue?

SPATIAL OBJECTS IN R



WHAT IS RASTER DATA?

Matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information.



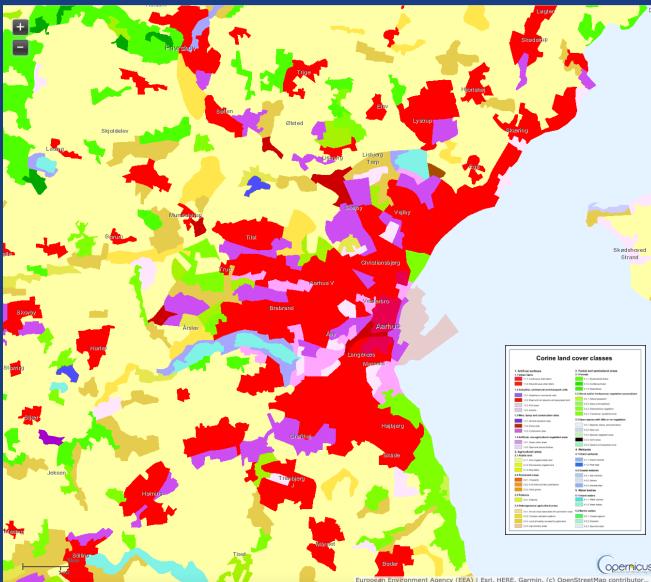
The information in these could be:

- Thematic data represents features such as land-use or soils data.
- Continuous data represents phenomena such as temperature, elevation, or spectral data such as satellite images and aerial photographs.
- Pictures include scanned maps or drawings and building photographs.



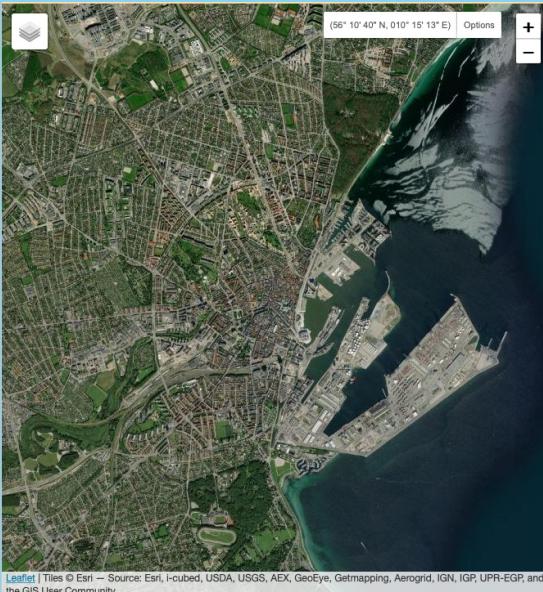
WHAT IS RASTER DATA?

Thematic data



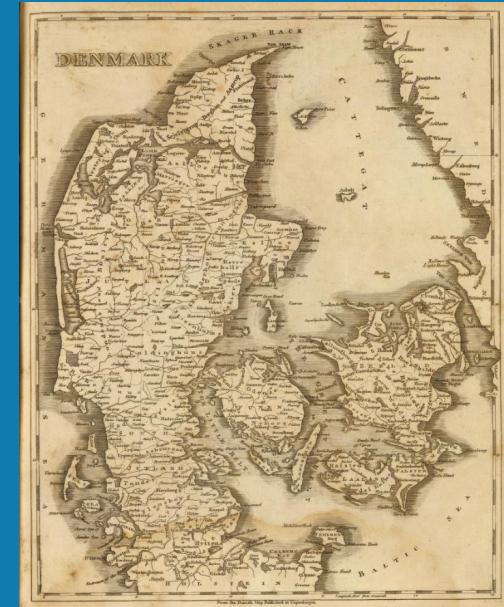
Land cover classification

Continuous data



Satellite image

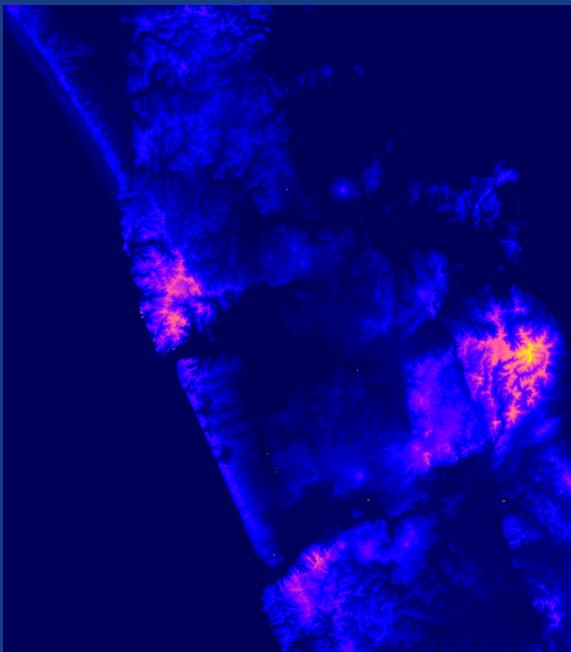
Pictures



Scanned map

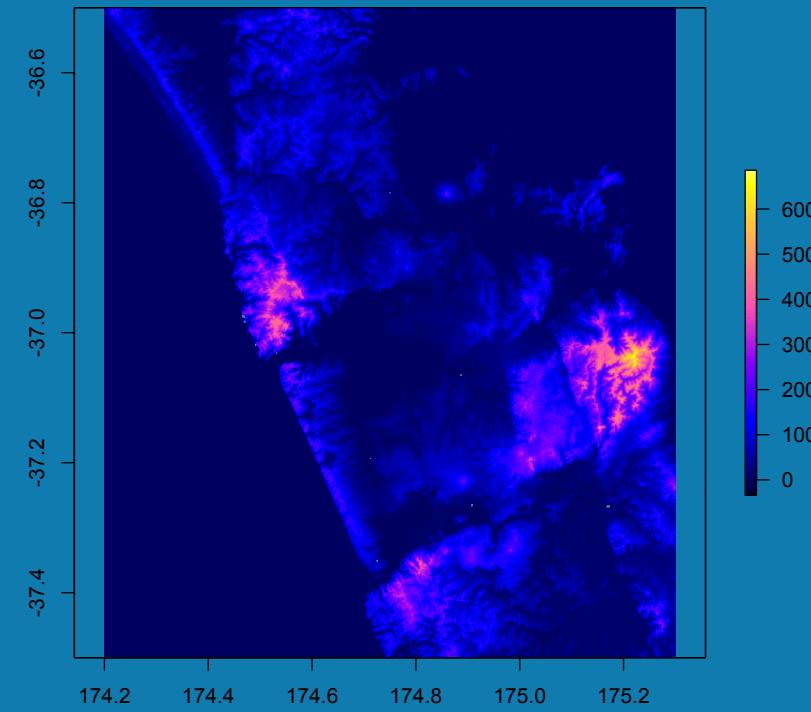
LOAD RASTER OBJECT TYPES IN R

SpatialGridDataFrame



Loaded with `rgdal:::readGDAL`

Raster Layer

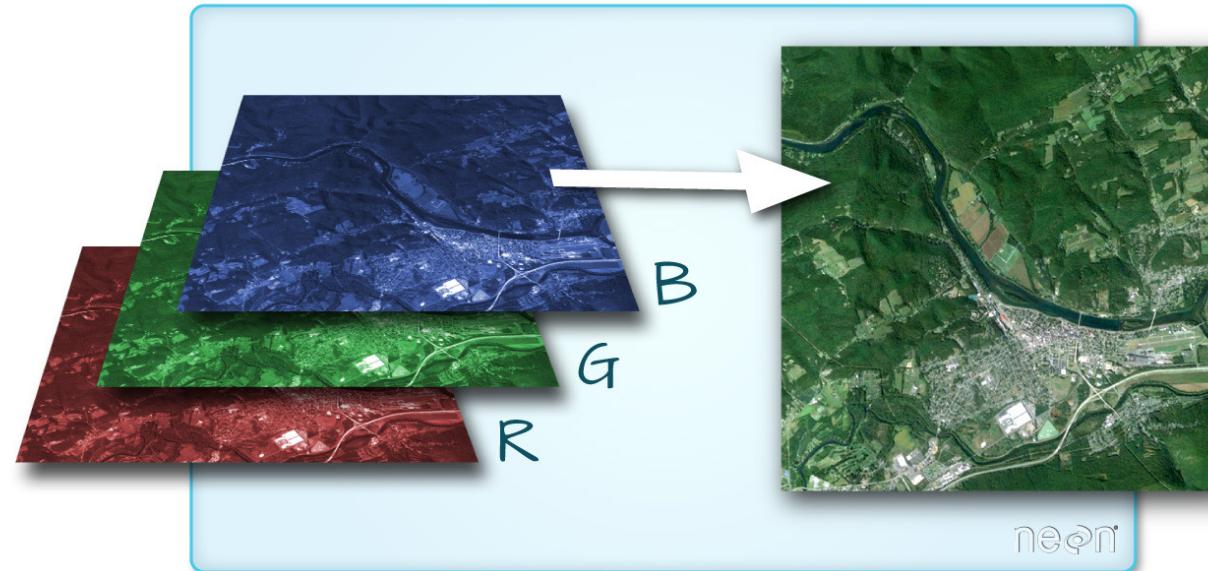


Loaded with `raster::raster`

SINGLE BAND AND MULTIBAND RASTER

A raster can contain one or more bands:

- A typical example is a colour image that consists of three bands: red, green, and blue.
- Based on how you combine these you can get true or false colour images



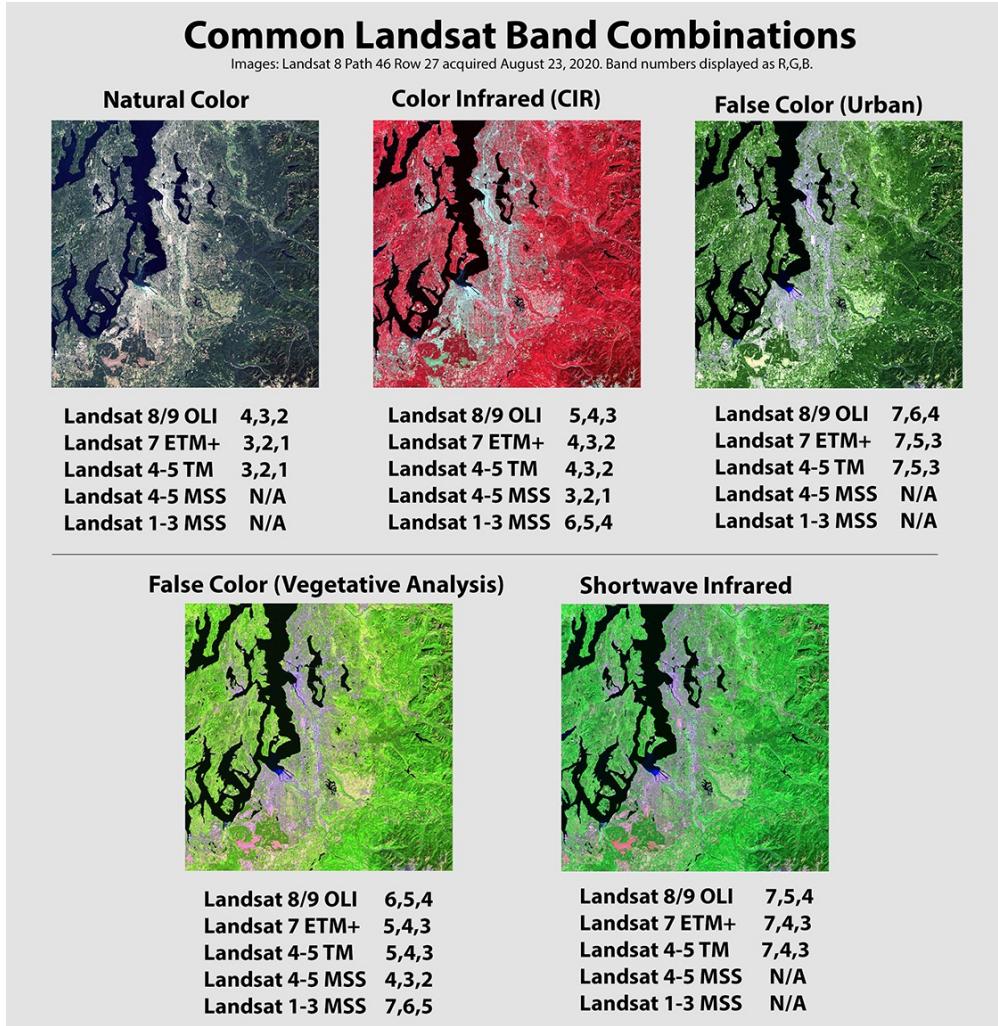
MULTIBAND REPRESENTATIONS

Based on how you combine multiple bands you can get different visualizations.

This is typically the case with satellite information that has many bands:

- e.g., Landsat-8 has 11 bands

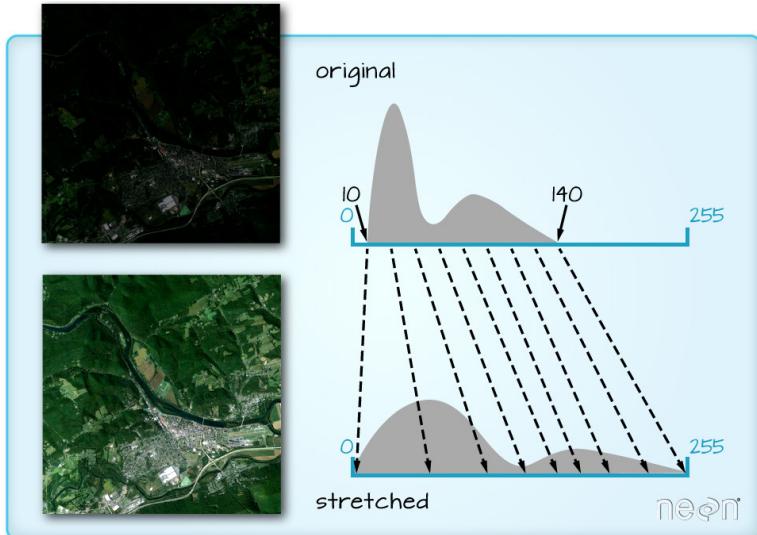
```
raster::plotRGB(Raster, BAND1, BAND2, BAND3)
```



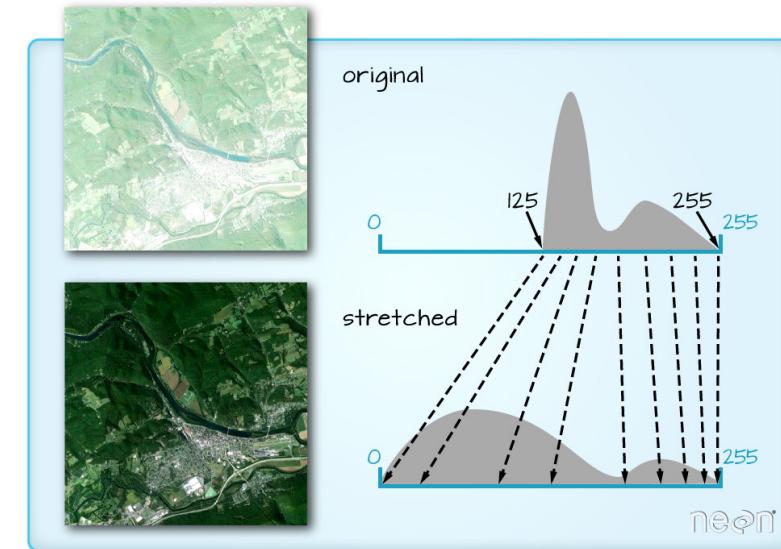
STRETCHING

Stretching the values in a raster can enhance an image by changing properties such as brightness, contrast, and gamma through multiple stretch types.

Brighten dark images



Darken oversaturated images



So far so good?

Any questions?

Ready to continue?

CELL-LEVEL FUNCTIONS ON RASTERS

Although Raster data can be thought of as a matrix when doing operations it is treated as a vector where the cell number defines the position.

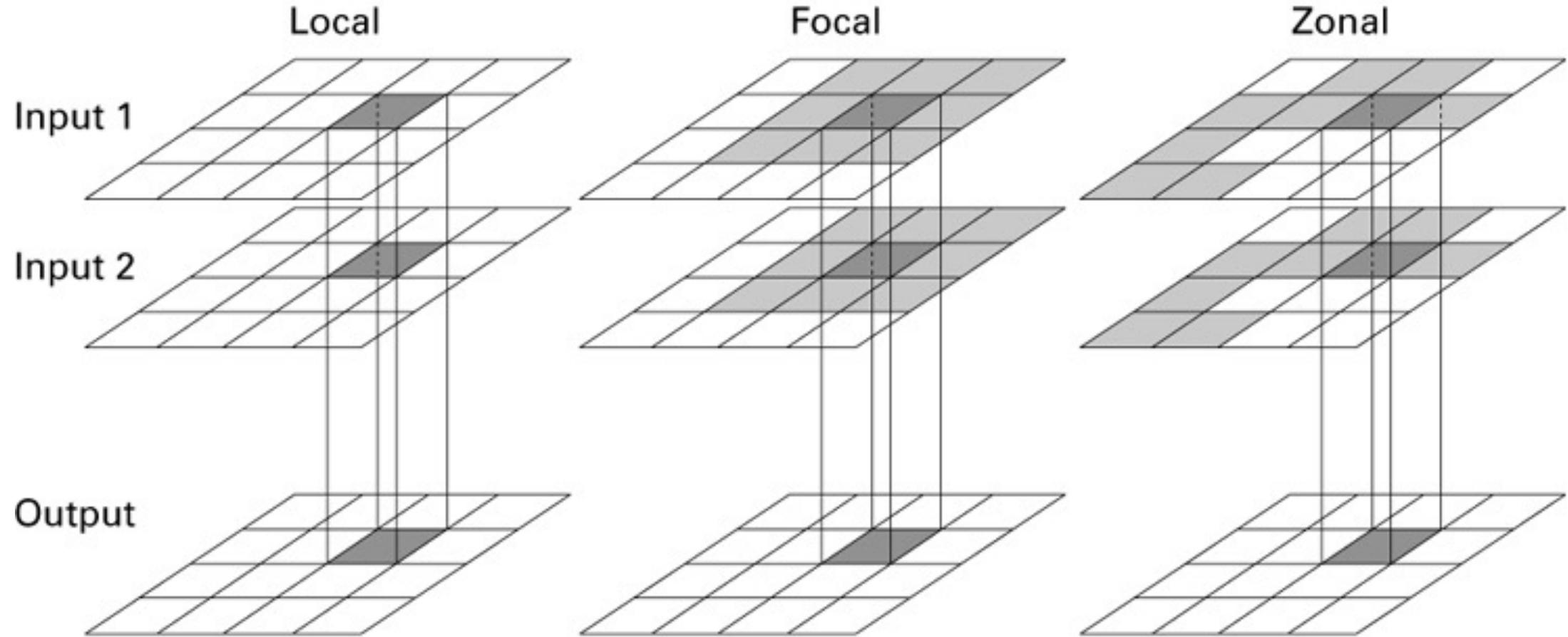
Cells are numbered continuously from top left to bottom right.

Basic transformations of a raster would be operations on a very long vector.

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

The diagram illustrates a 5x5 raster grid with cells numbered sequentially from 1 to 25. Red arrows show the path of the sequence: 1 to 2 to 3 to 4 to 5 (top row), 6 to 7 to 8 to 9 to 10 (second row), 11 to 12 to 13 to 14 to 15 (third row), 16 to 17 to 18 to 19 to 20 (fourth row), and 21 to 22 to 23 to 24 to 25 (bottom row). The arrows also indicate the direction of the sequence: right, down-right, down, down-right, and finally right again at the bottom.

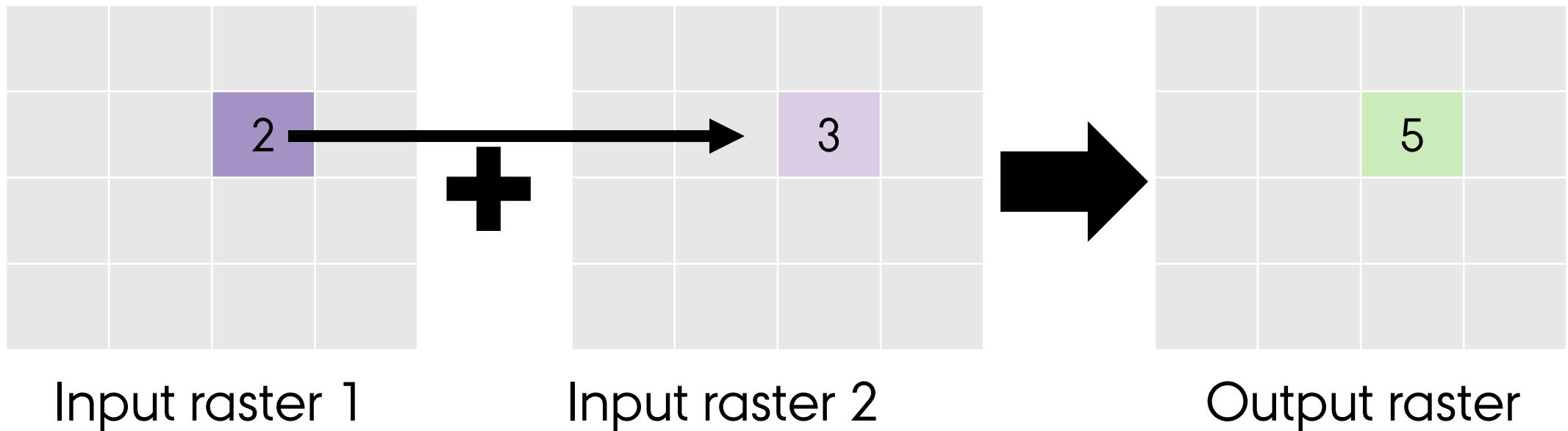
MAP ALGEBRA



LOCAL OPERATIONS

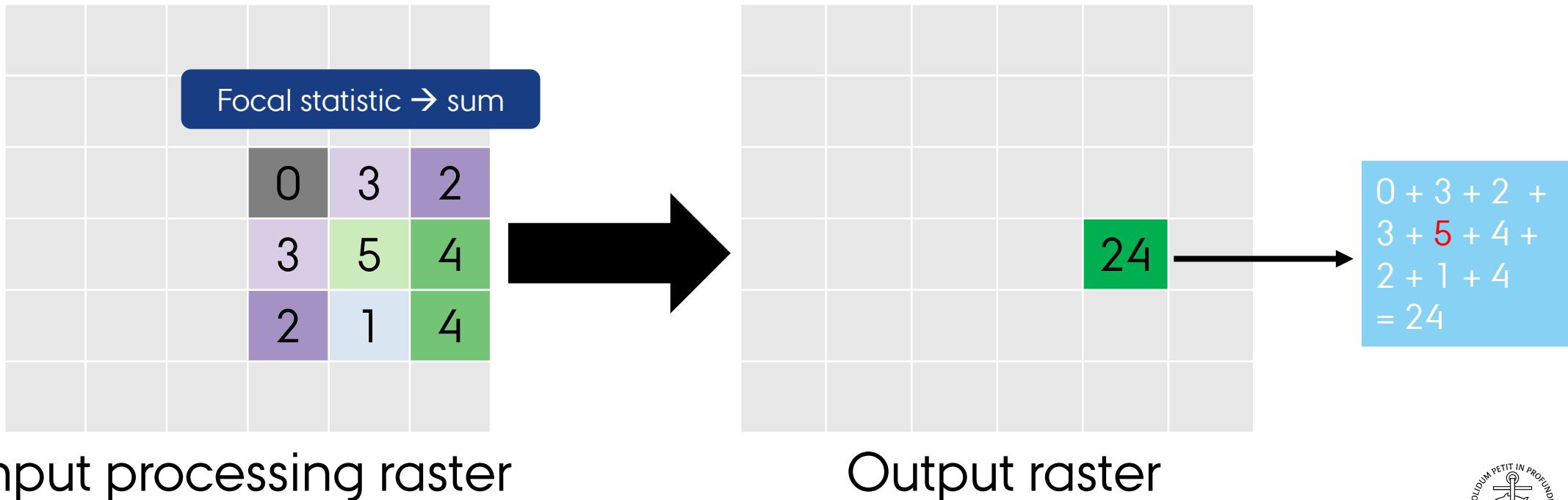
Basic operations will be element by element

- The same operation is done to each cell.
- Calculations are based on overlapping.



FOCAL STATISTICS

- Summarizes all the input cells that are in a specified neighbourhood.
- Neighbourhoods can have different sizes n X/Y directions



ZONAL STATISTICS

- A single output value is computed for every zone in the input zone dataset.
- A zone is all the cells in a raster that have the same value, whether or not they are contiguous.

1	1	0	0
	1	2	2
4	0	0	2
4	0	1	1

Zone raster

0	1	1	0
3	3	1	2
	0	0	2
3	2	1	0

Values raster

Zonal statistic → max



3	3	2	2
	3	2	2
3	2	2	2
3	2	3	3

Output raster

So far so good?

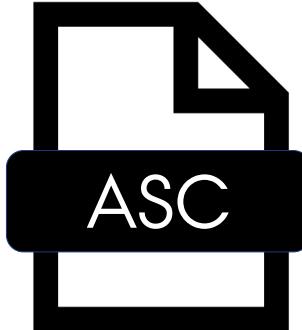
Any questions?

Ready to continue?

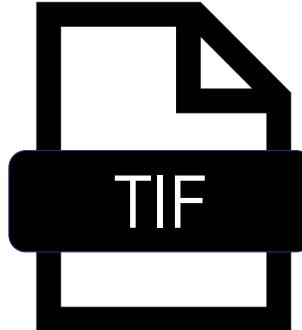
RASTER FORMAT TYPES



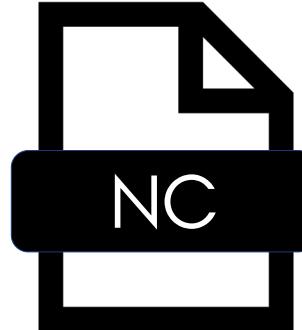
GRD



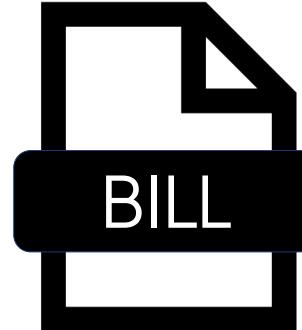
ASC



TIF



NC



BILL



IMG

Native' raster package format

ESRI Ascii

GeoTiff requires rgdal

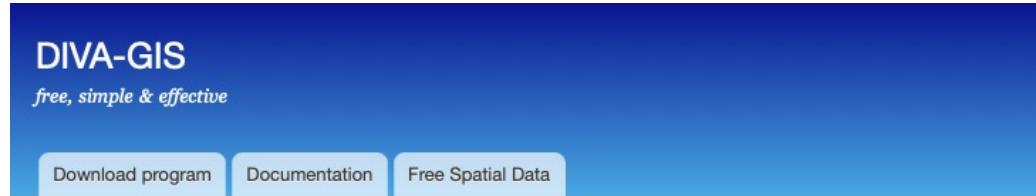
netCDF requires ncdf4

ESRI native raster format

Erdas Imagine Images

All these can be loaded using either rgdal (`readGDAL`) or raster (`raster`) functions

WHERE I CAN FIND RASTER DATA BASE RASTERS



Home

Download data by country

Select and download free geographic (GIS) data for any country in the world

Country

Denmark

Subject

Administrative areas

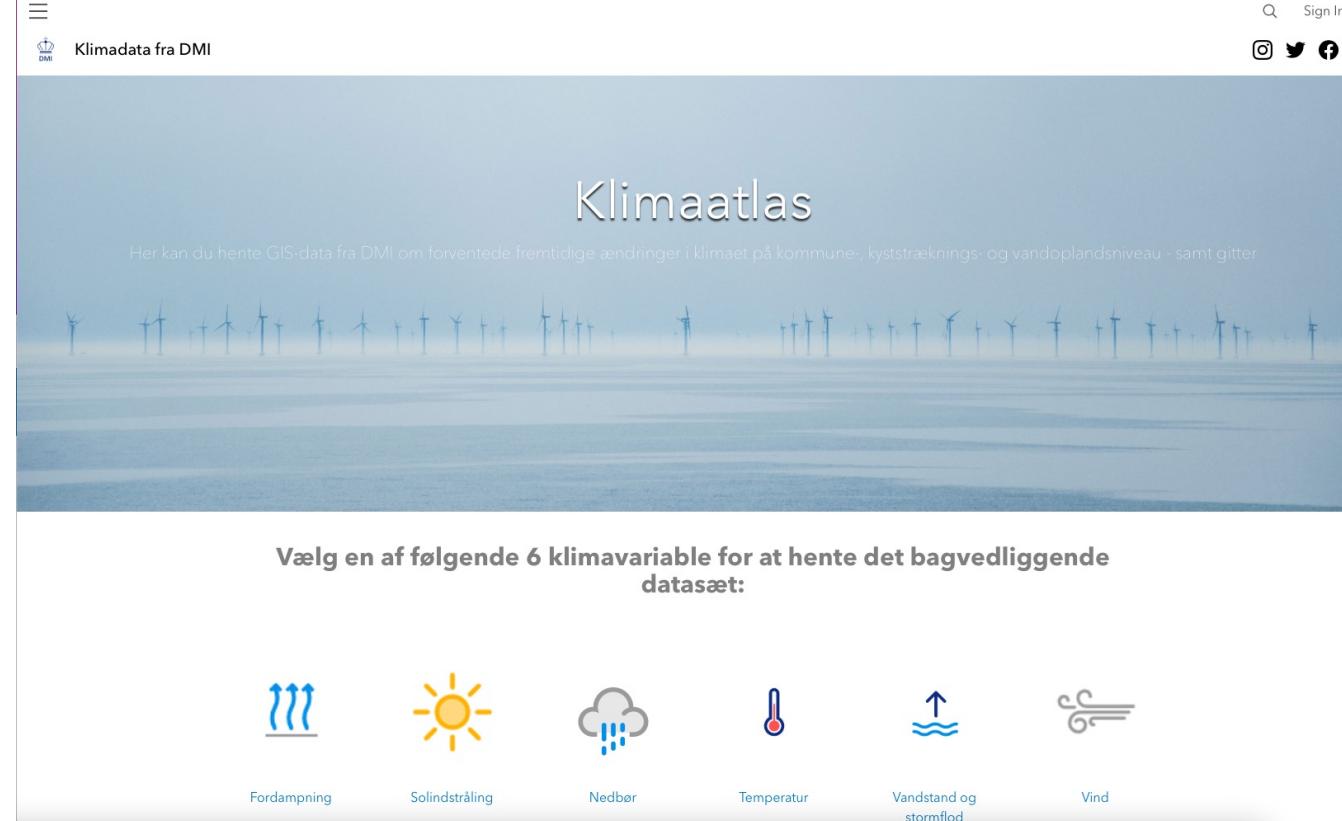
OK

Sources

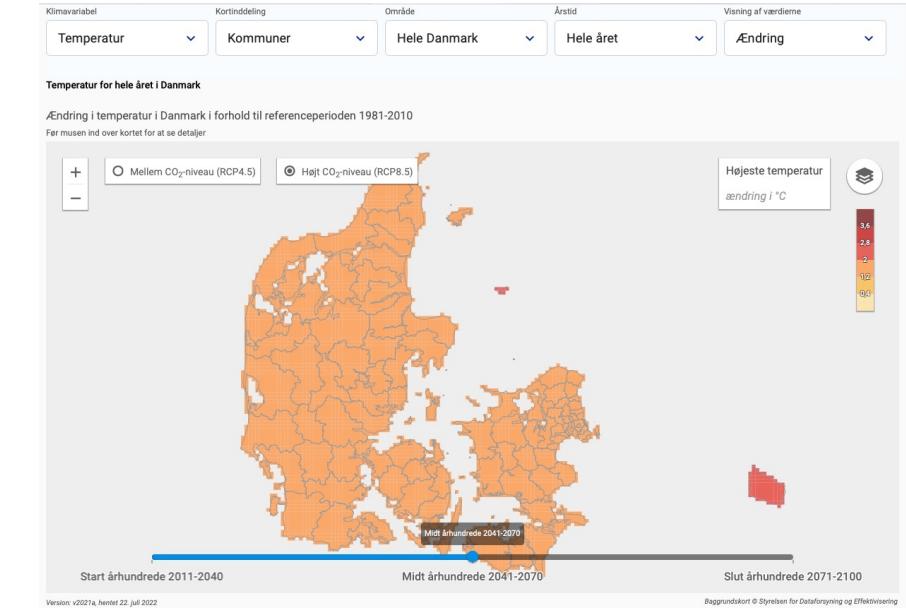
Subject	Description	Source	Format	Resolution
Elevation	SRTM30 dataset. CGIAR-SRTM data aggregated to 30 seconds	CGIAR SRTM (3 seconds resolution)	Grid	30 seconds
Land cover	Land cover, original data resampled onto a 30 seconds grid	GLC2000	Grid	30 seconds
Population	Population density (old)	CIESIN, 2000. Global gridded population database	Grid	30 seconds
Climate	Monthly climate data	WorldClim	Grid	30 seconds

<https://bit.ly/2H9ZZ9d>

WHERE I CAN FIND RASTER DATA CLIMATE VARIABLES



<https://klimaatlas-dmidata.opendata.arcgis.com>



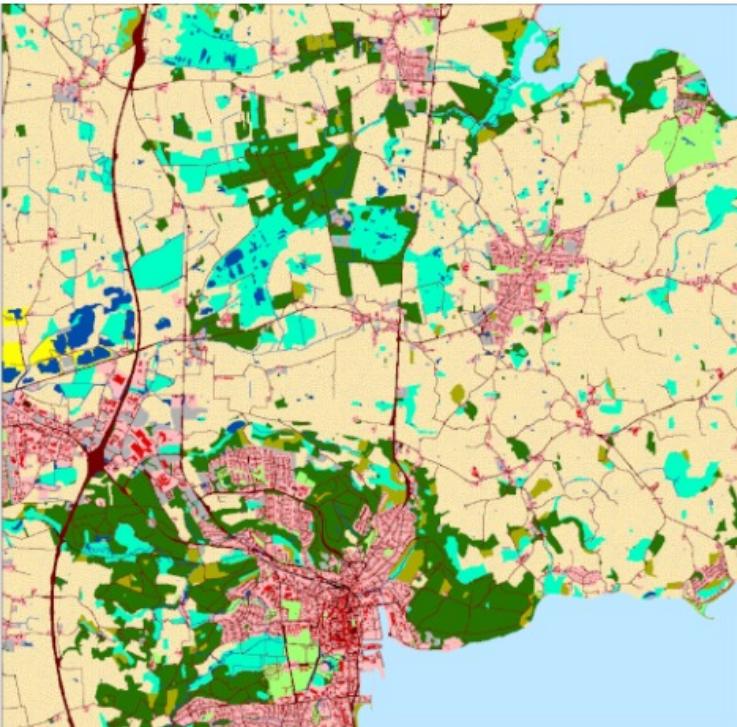
There is a web portal to visualize the data
<https://bit.ly/3z1teF7>

WHERE I CAN FIND RASTER DATA LAND COVER

BASEMAP

[Land use 1990 – 2017]

- █ Building
- █ Urban / built up
- █ Rail
- █ Road
- █ Recreational area
- █ Resource extraction
- █ Agriculture
- █ Forest
- █ Nature open, dry
- █ Nature open, wet
- █ Lake / stream
- █ Sea
- █ Unclassified



National map of land use
and land cover for
Denmark at a 10x10

Land use maps for
2005, 2011 and 2017
are ready!

<https://bit.ly/3BAXERJ>

WHERE I CAN FIND RASTER DATA SPECIFIC ENVIRONMENTAL DATA

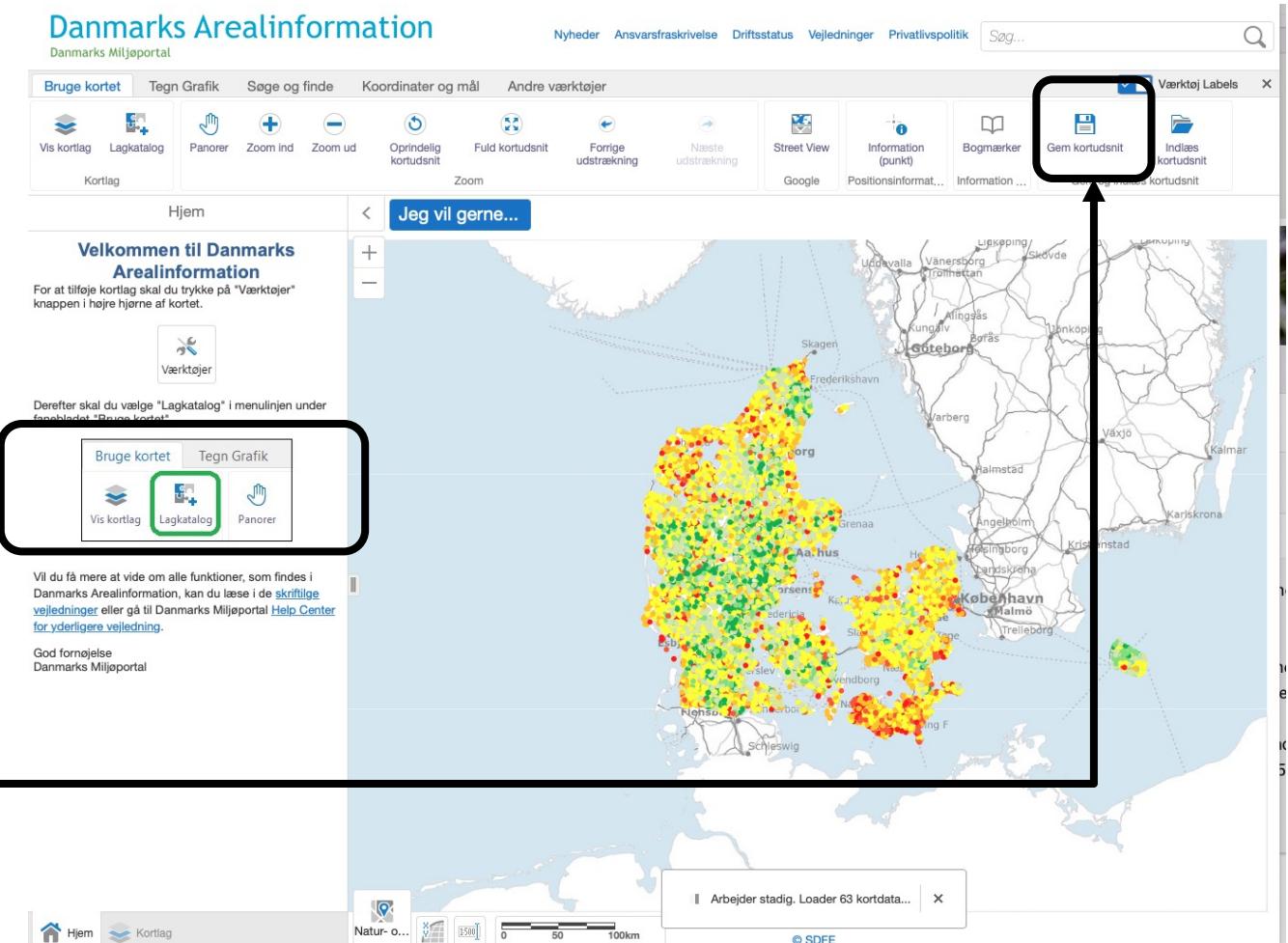
Danmarks Miljøportal
Data om miljøet i Danmark

<https://miljoeportal.dk>

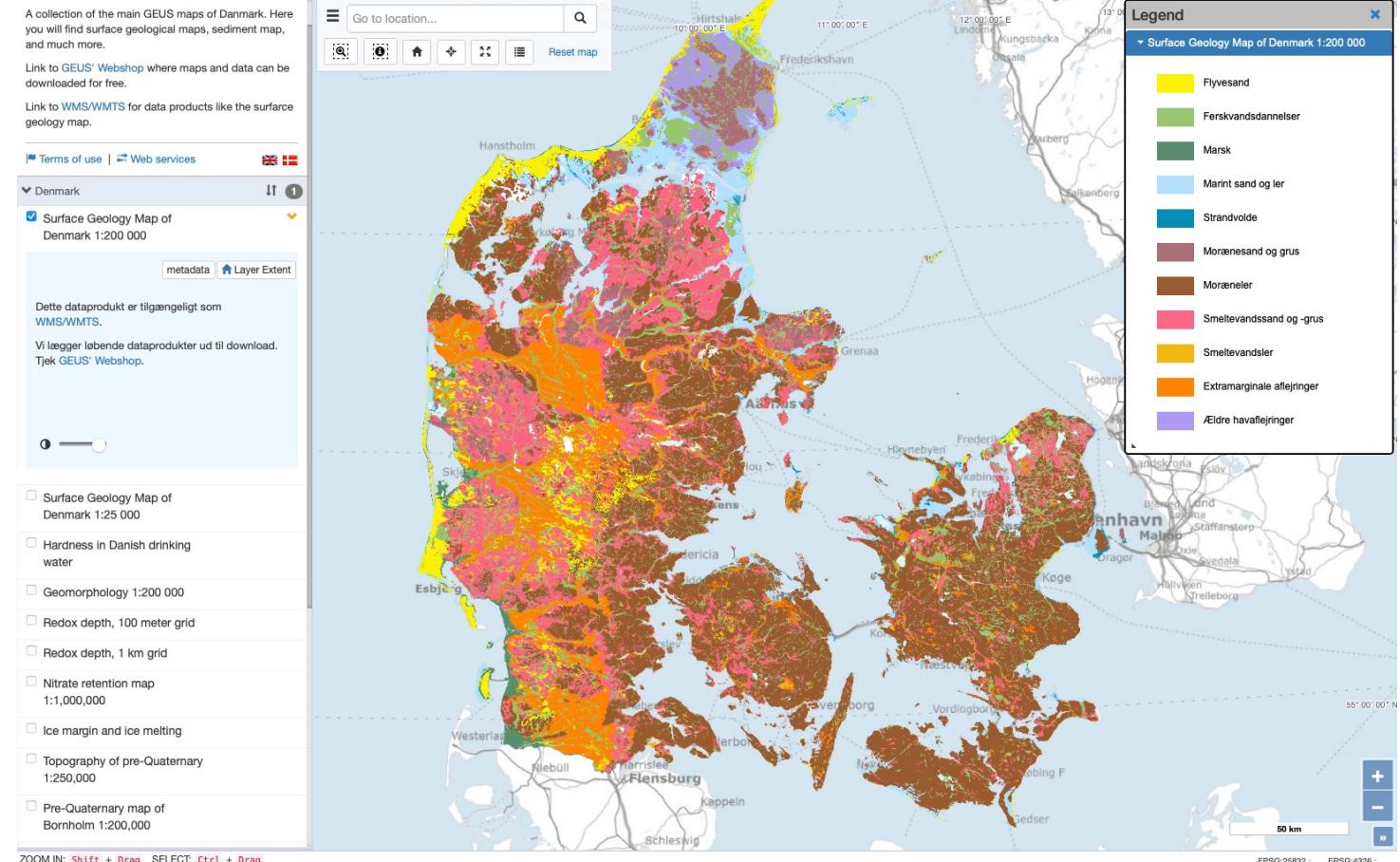
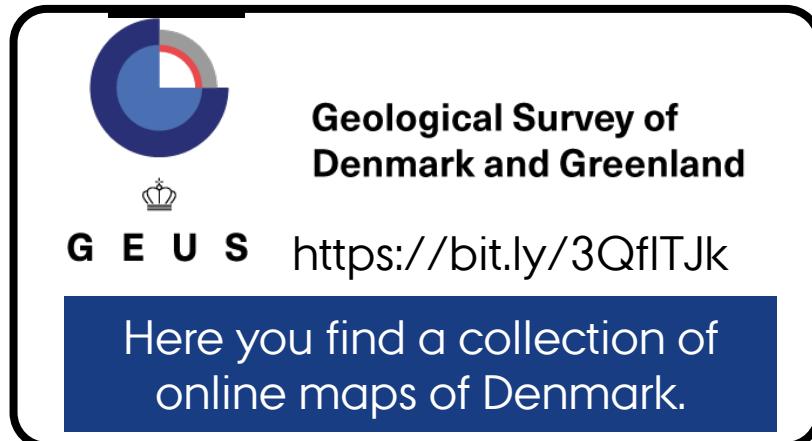
Main data source for Danish biological Data.

1. Define the variable to plot

2. Get a URL to the Map



WHERE I CAN FIND RASTER DATA SOILS AND GEOLOGICAL ATTRIBUTES



WHERE I CAN FIND RASTER DATA HIGH RESOLUTION FOR EUROPE



The most comprehensive source of baseline and high resolution spatial data for Europe

Copernicus Services



There are different Monitoring Services

The most mature is the **Land Monitoring Service**



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