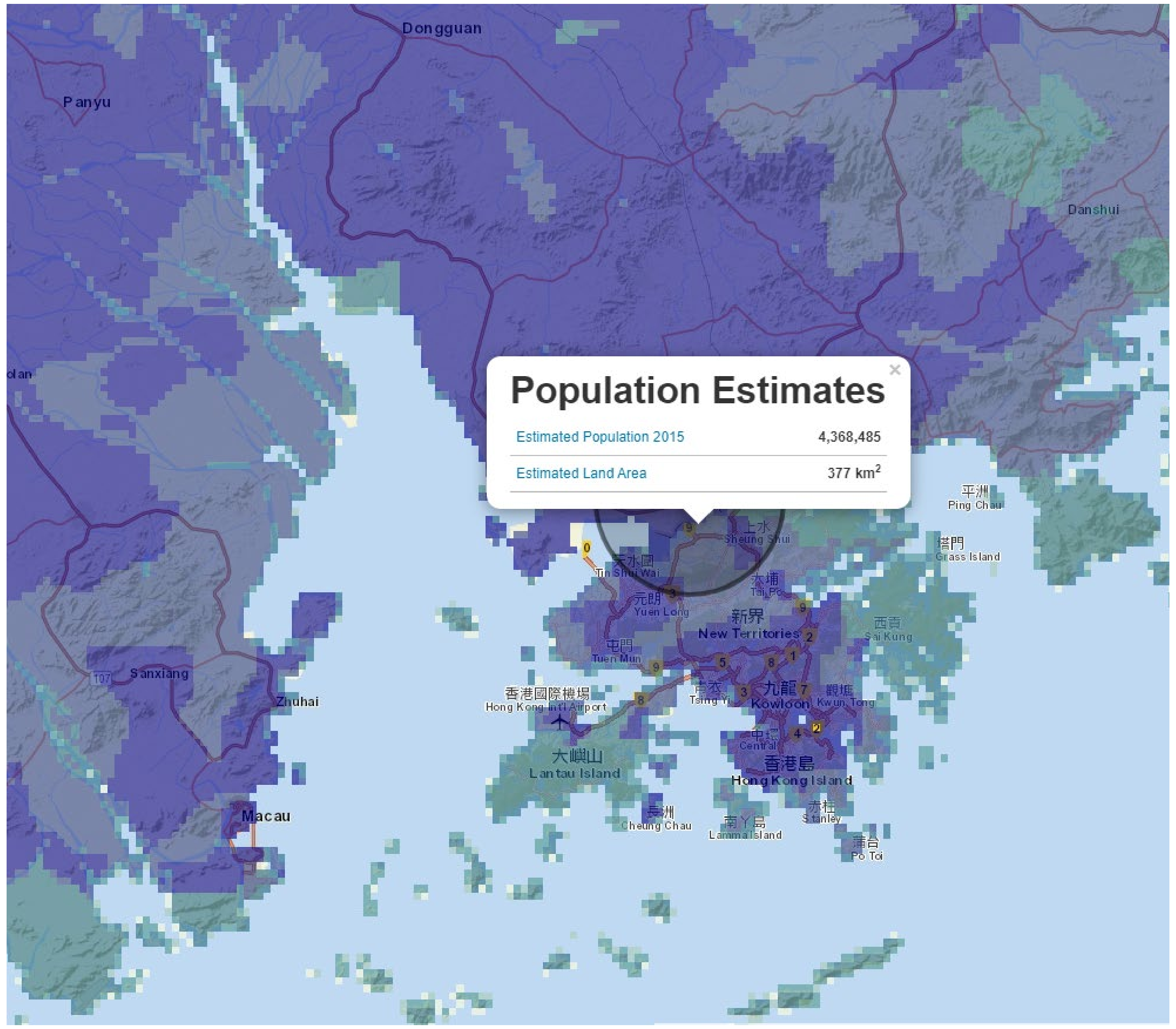
Geospatial Data Science, Spring 2023

Lecture 10: Field-based analysis



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Apr 3, 2023

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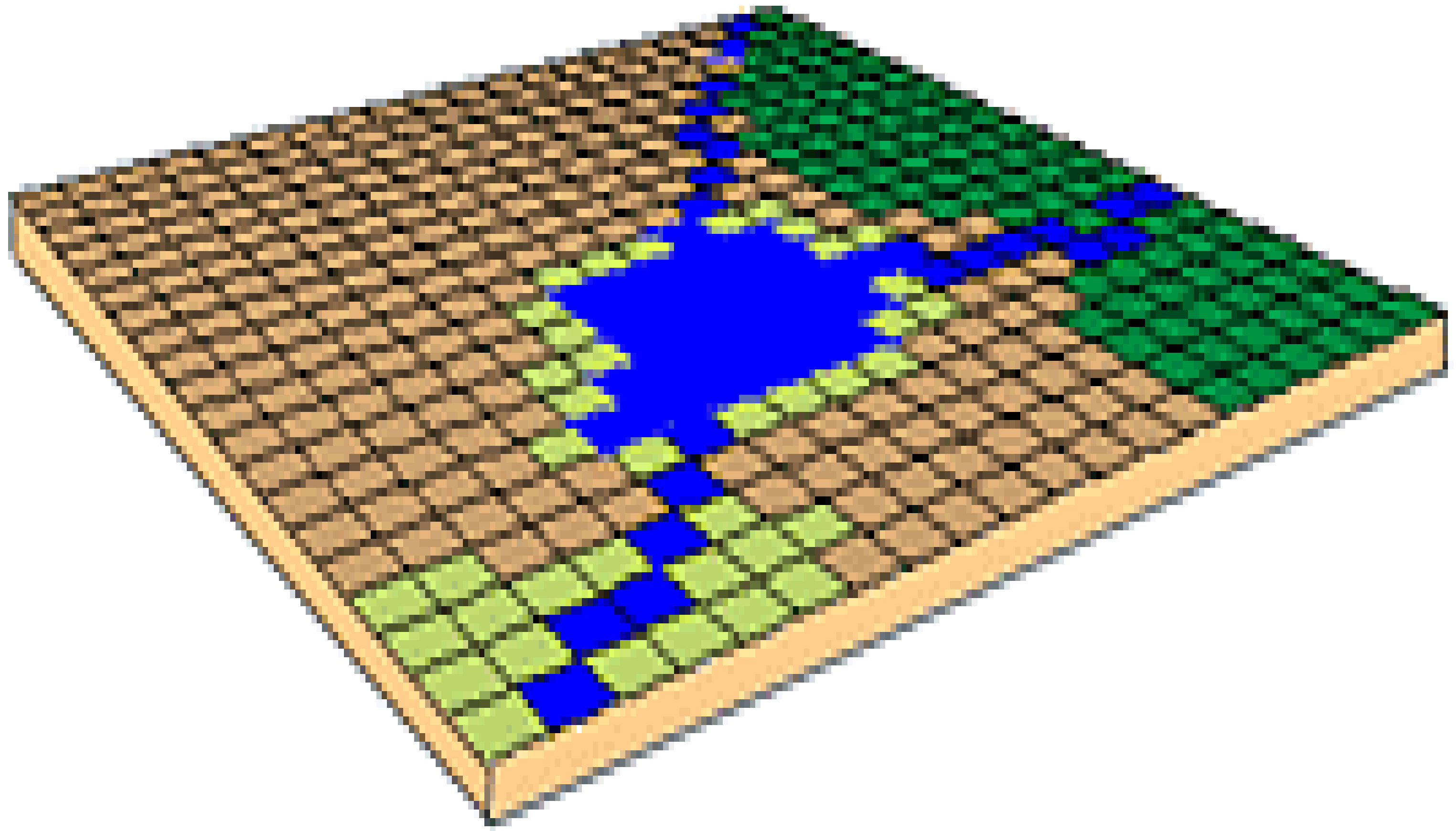
Objectives & agenda

- Introduction to raster layers
- Applications
- DEM and derivations
- Map Algebra

Field-based model → Raster

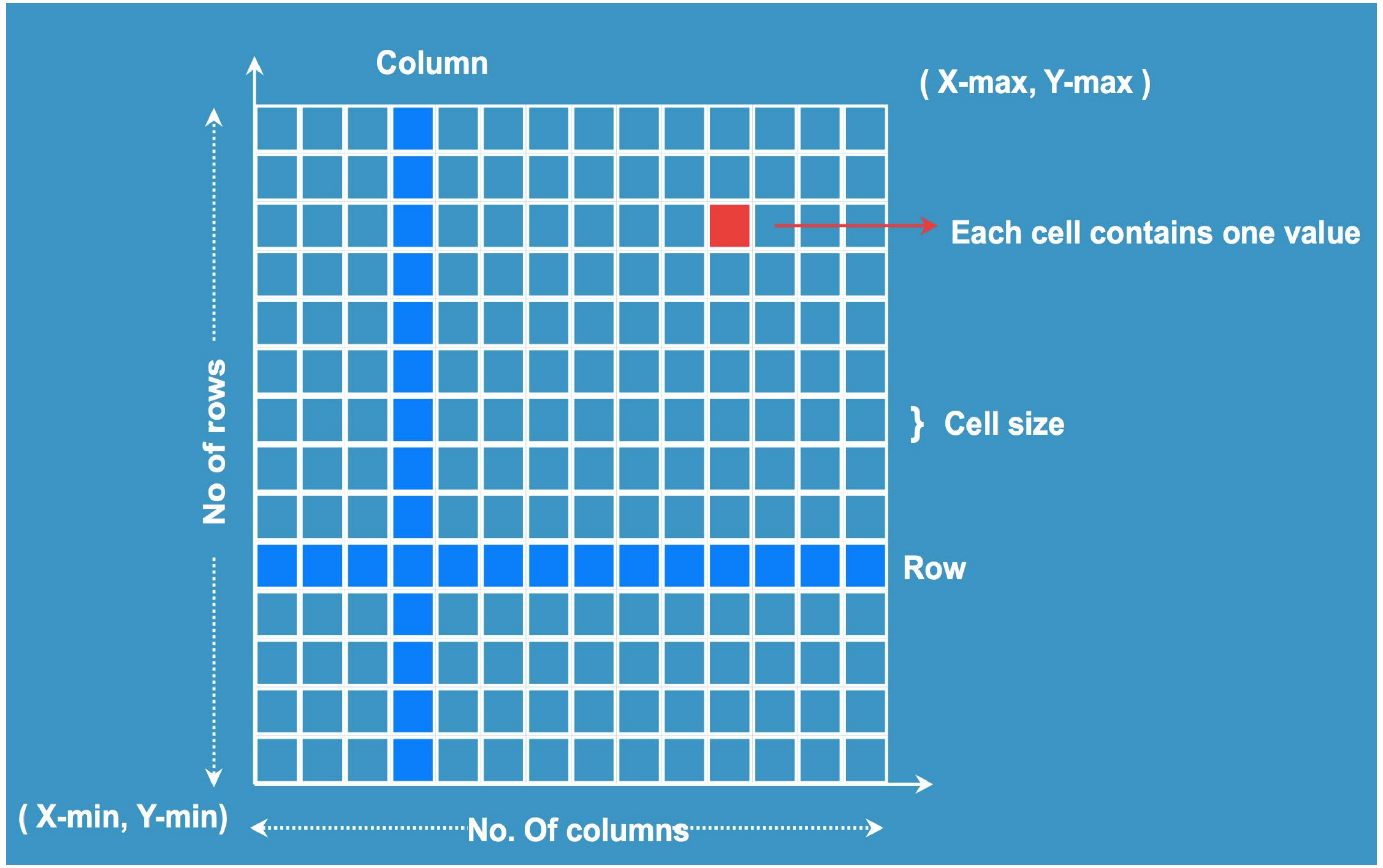
The field-based model represents the world as fields of attributes that have values everywhere in space.

- Raster data is characterised by pixel values.
- Representation of **continuous** data



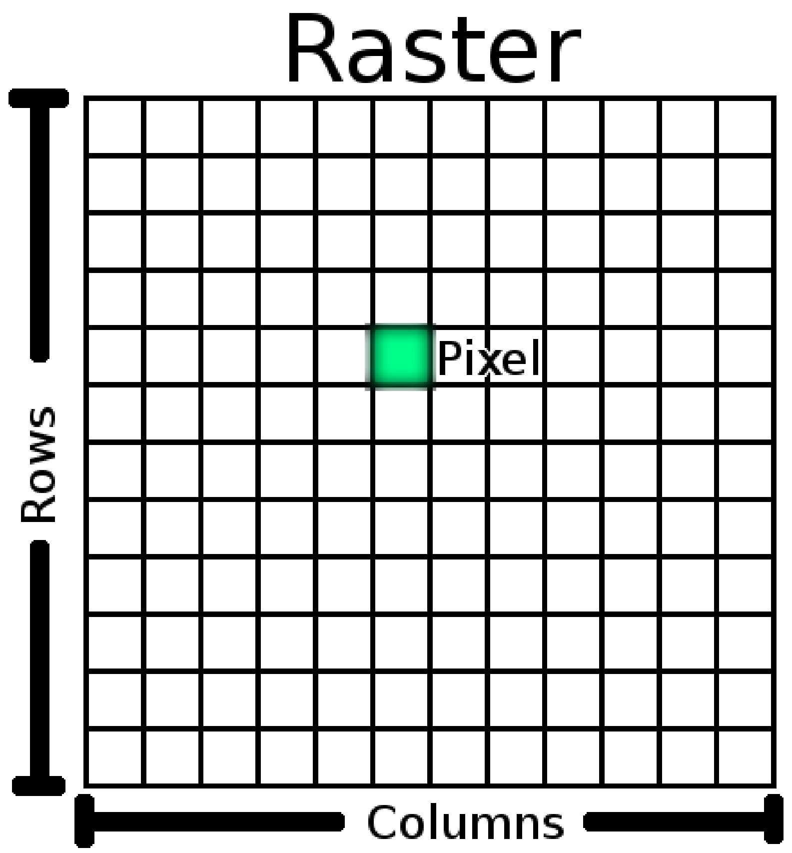
Raster Structure

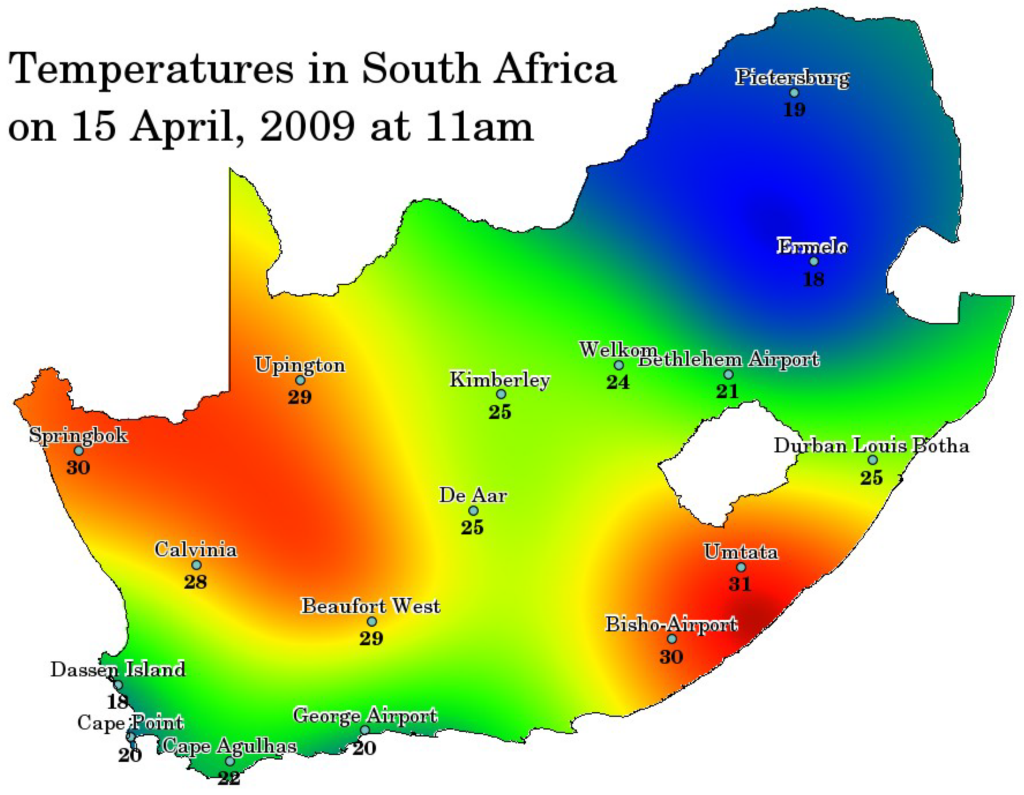
- Georeferenced “frame”
- Split up into evenly sized cells
- Every cell holds one numeric value

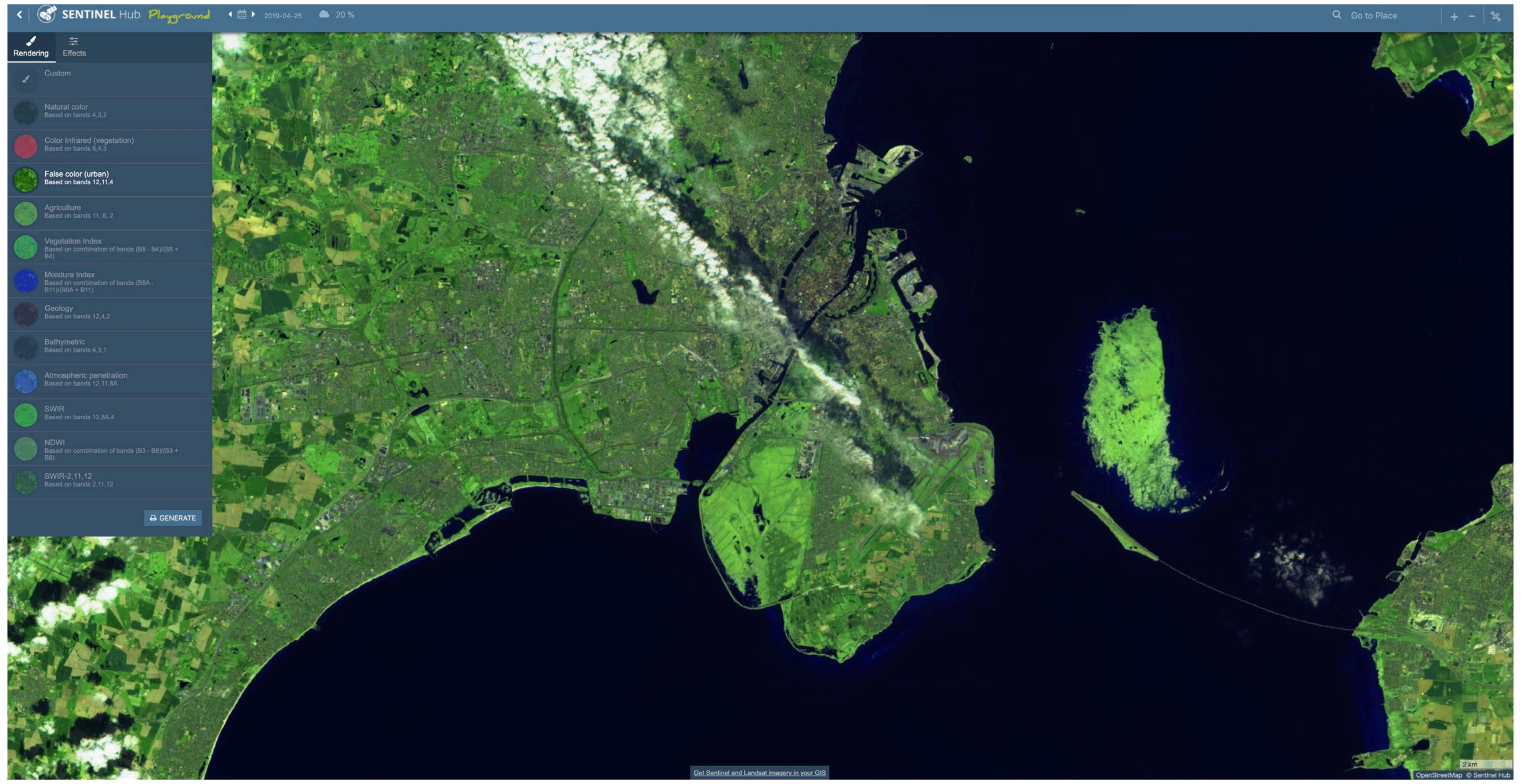


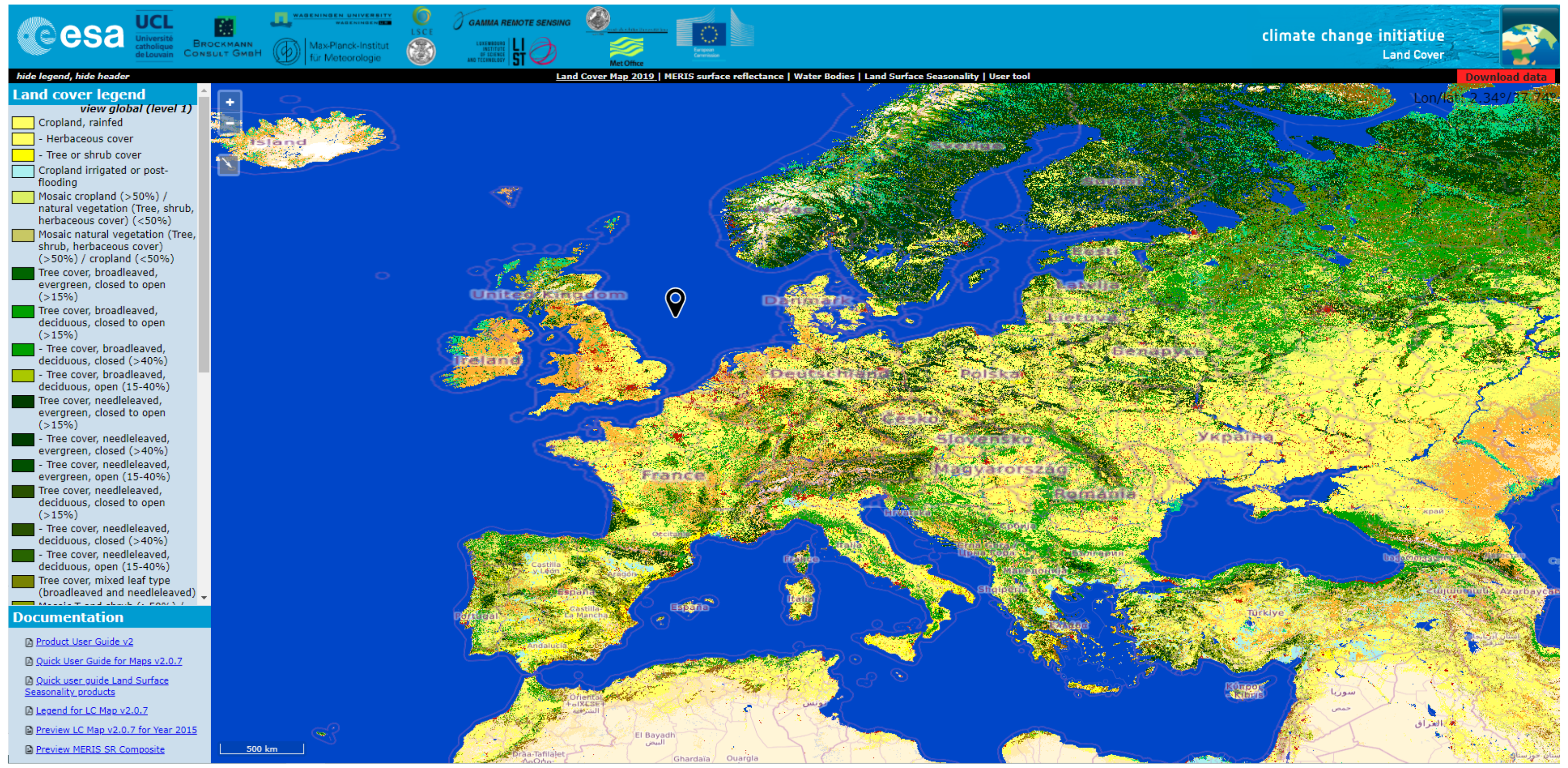
Examples

- Satellite Images
- Elevation map
- Temperature (Interpolation)
- Land Cover data (ESA-CCI)



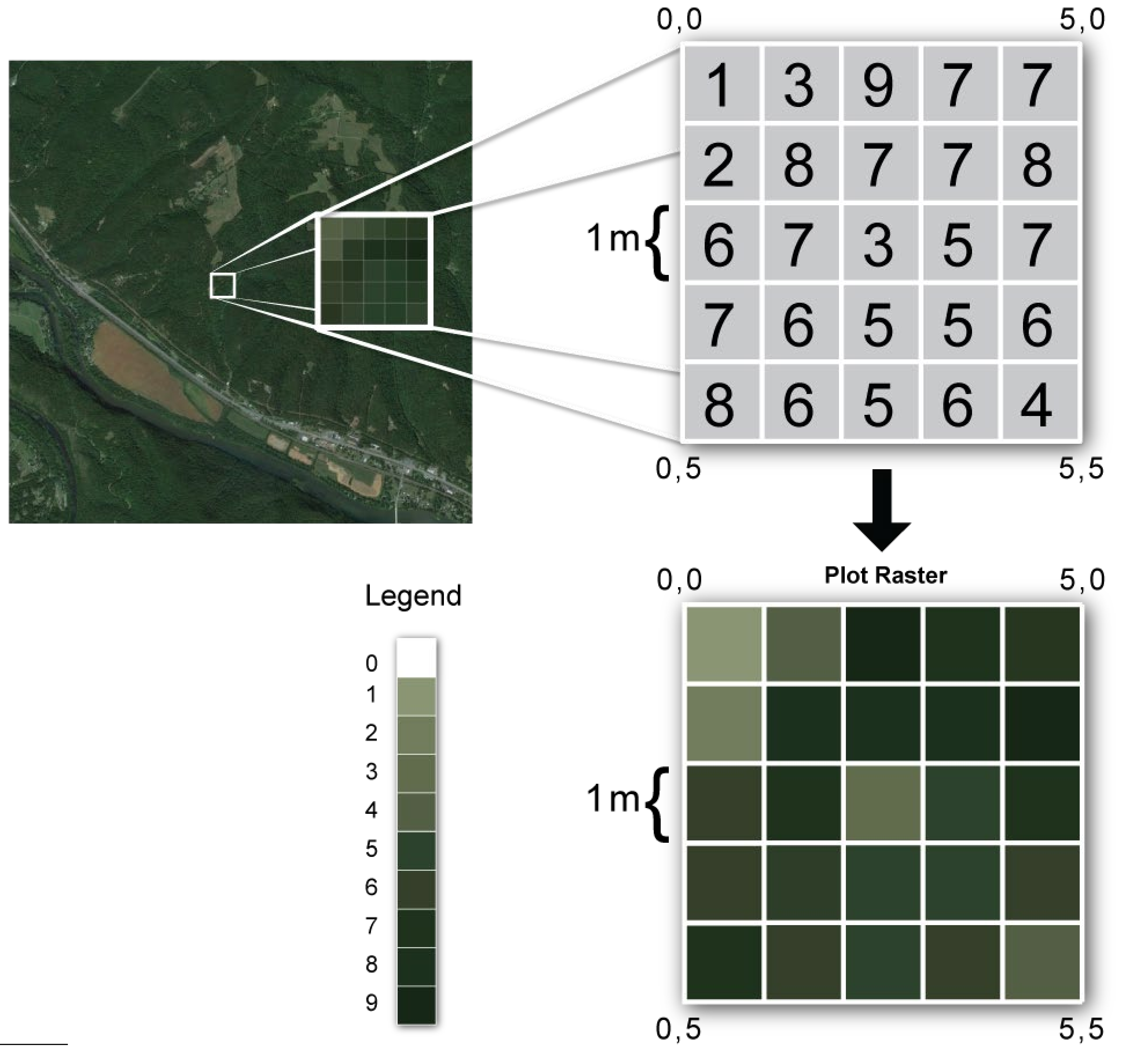






Rasters

- Raster data is pixelated data where each pixel is associated with a specific location.
- Raster data always has an extent and a resolution.
- Raster values may be continuous or categorical
- Rasters can contain one or more bands.



https://datacarpentry.org/organization-geospatial/01-intro-raster-data/

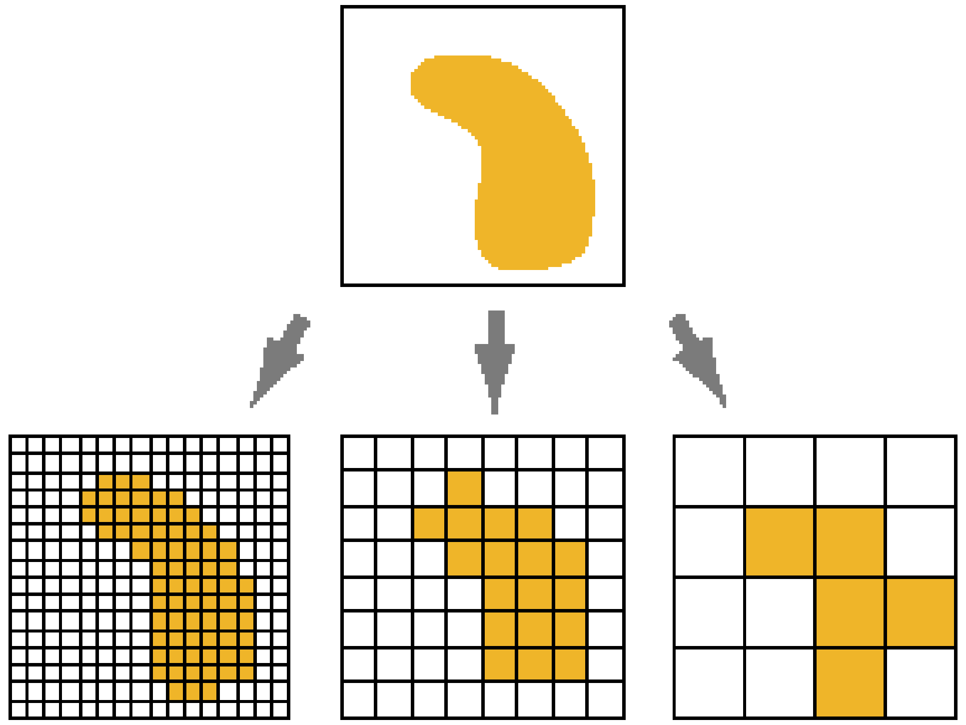
Raster have extent

- Raster data always has an extent and a resolution.

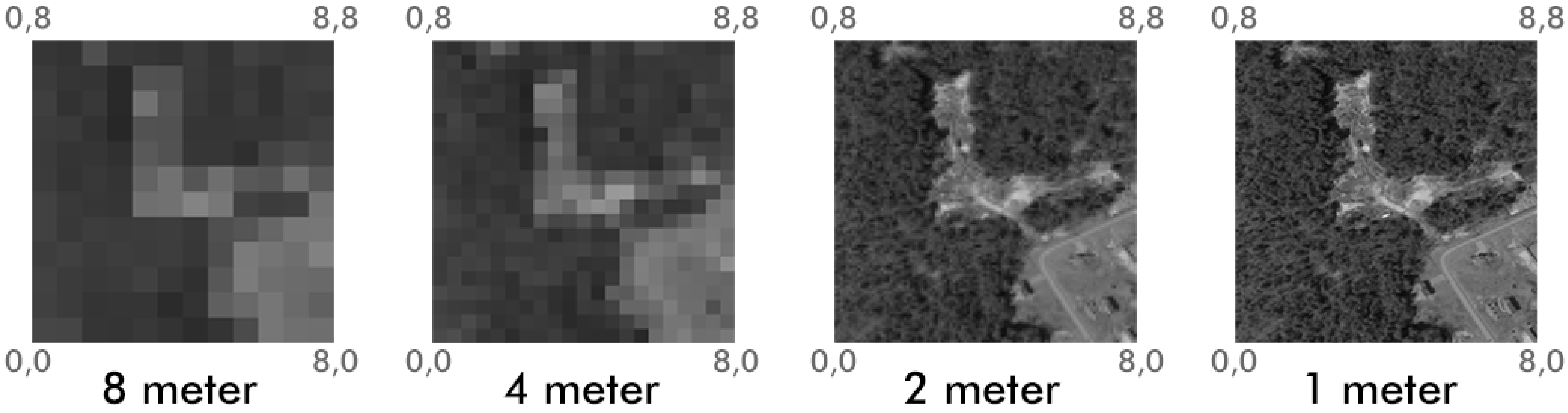
- The extent is the geographical area covered by a raster
    - Number of rows
    - Number of columns
    - Coordinate system

Rasters have spatial resolution

- Raster data always has an extent and a resolution.
- The resolution is the area covered by each pixel of a raster.

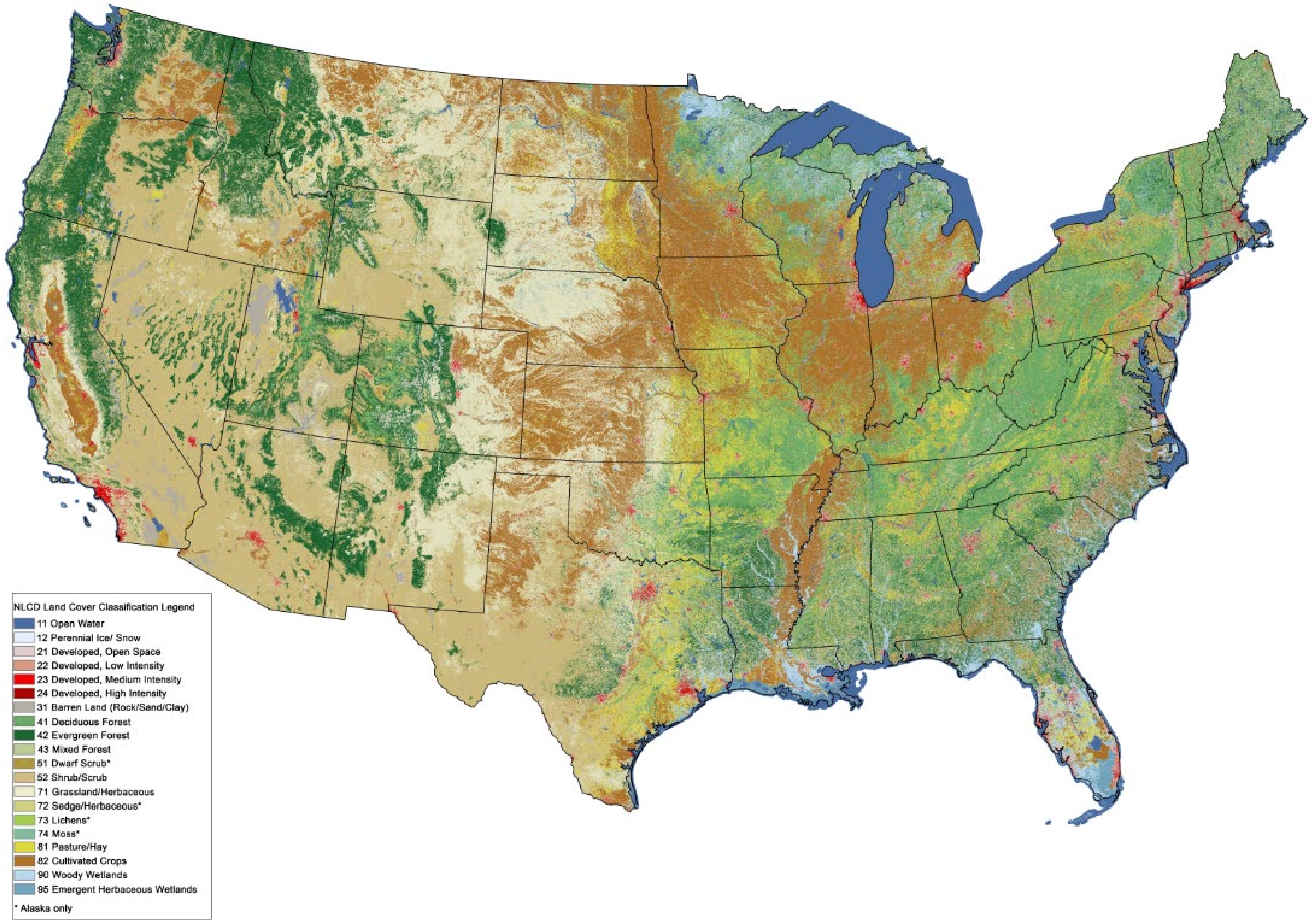


Raster over the same extent, at 4 different resolutions



Discrete VS continuous raster values

- Discrete rasters have distinct themes or categories.
- Examples: land cover class, soil type

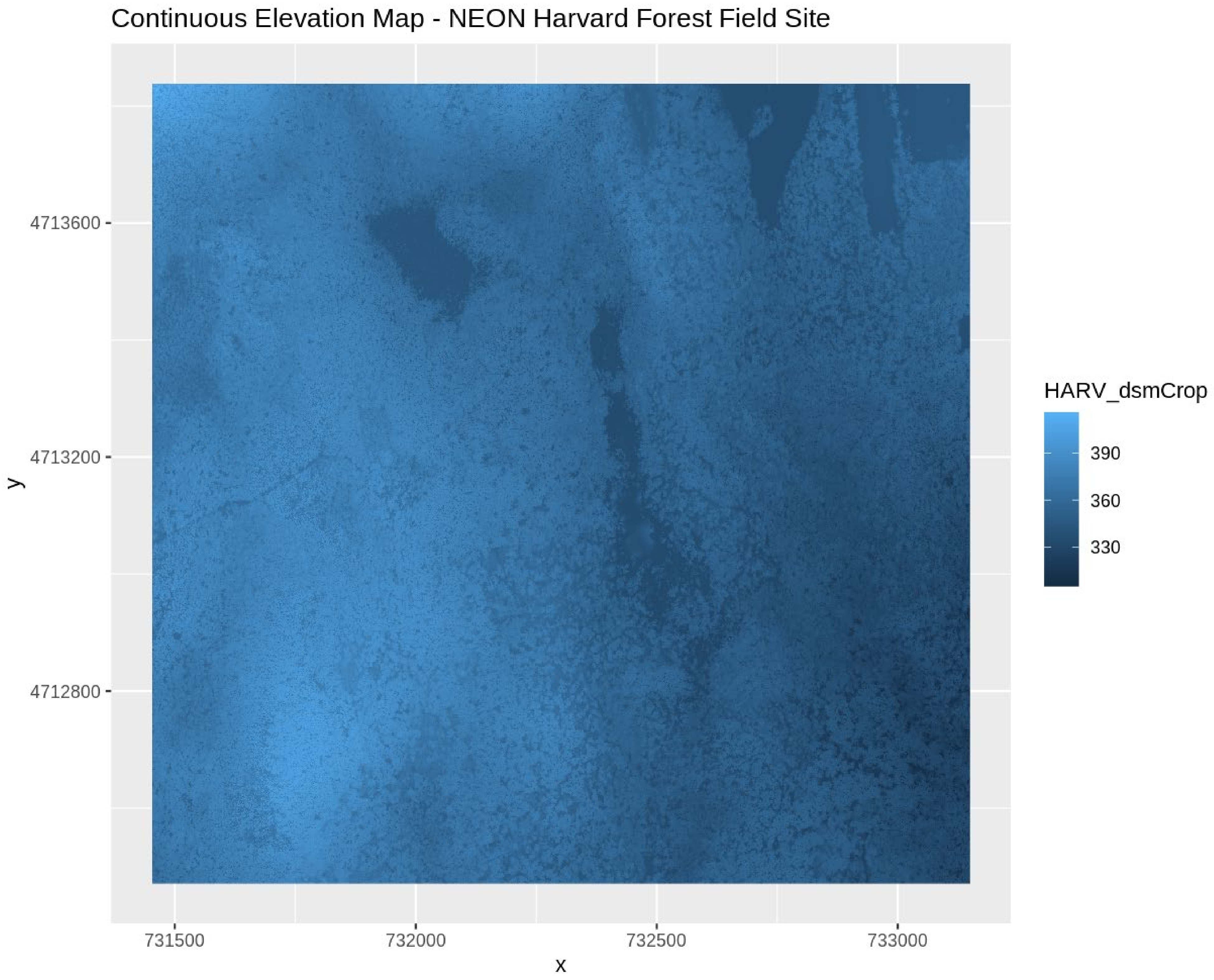


https://gisgeography.com/spatial-data-types-vector-raster/

Discrete VS continuous raster values

- Continuous rasters (non-discrete) are grid cells with gradually changing data

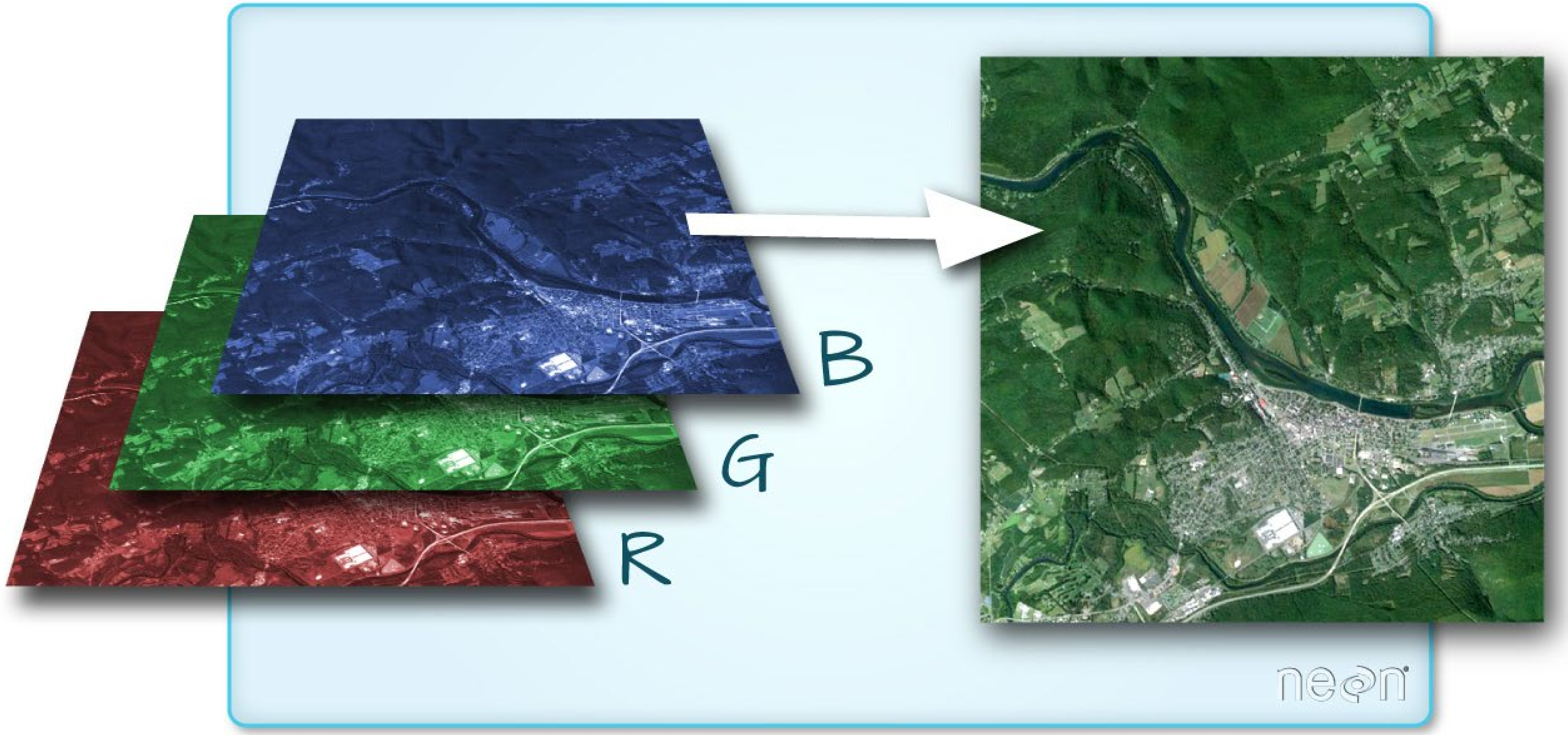
- Examples: elevation, temperature, aerial photograph.



Raster bands

Different bands can be used to combine several “layers” in one file (satellite images)

Each of those bands/layers can only represent one attribute



Raster bands

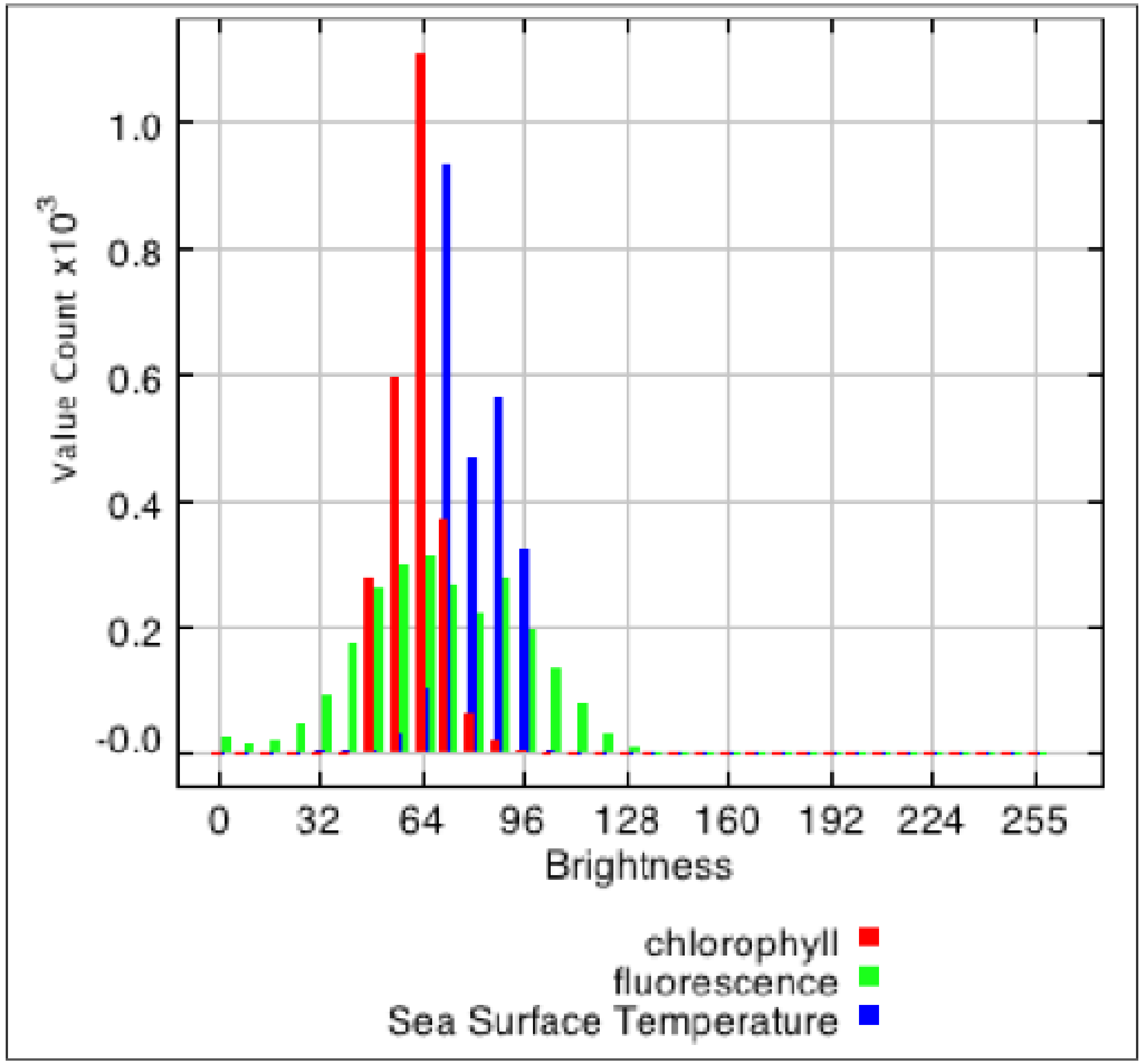
Multi-band raster data might also contain:

- Time series: the same variable, over the same area, over time.
- Multi or hyperspectral imagery: image rasters that have 4 or more (multi-spectral) or more than 10-15 (hyperspectral) bands. → merge multiple raster layers into 1

Histogram

- It shows the statistical distribution of the values in a raster.

- Horizontal axis → the unique values in the dataset
- Vertical axis → the frequency of this value in the raster



Practically, in python …

- Main data format: *.tif*
- Main python libraries: *gdal, rasterio*

```
# Open the file:
dsm = rasterio.open('./data/DSM.tif’)
print("The file is called", dsm.name)
print("It is", dsm.width, "x",dsm.height,"pixels big")
print("It covers the following extent:",dsm.bounds)
print("It is in the following CRS:",dsm.crs)
print(“Number of bands:",dsm.count)
```

Practically, in python …

```
import matplotlib.pyplot as plt
%matplotlib inline

# Plot the raster
plt.figure(figsize=(7, 7))
show((dsm, 1), title='DSM', cmap='Greys’)

# Plot the histogram
from rasterio.plot import show_hist
show_hist(
    dsm, bins=50, lw=0.0, stacked=False, alpha=0.3,
     title="Histogram")
```

Raster Data

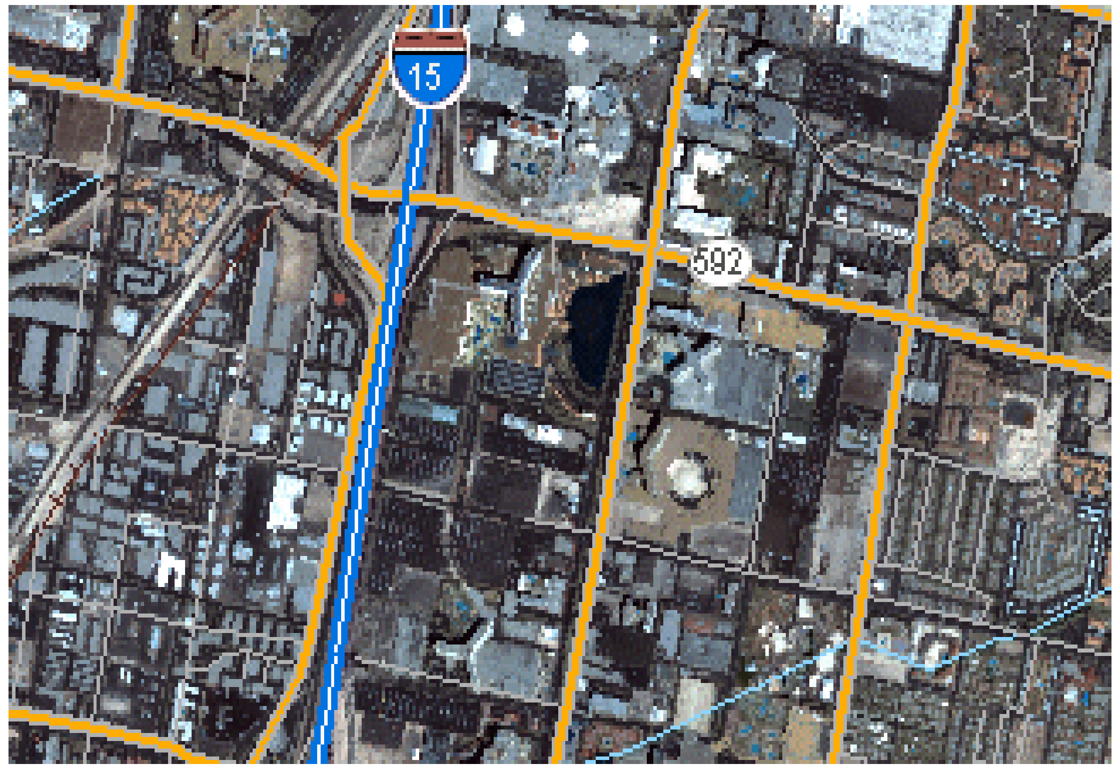
- Representing continuous data (e.g., slope, elevation, temperature)
- Representing multiple feature types (e.g., points, lines, and polygons) as single feature types (cells)
- Rapid computations (*Map Algebra*) in which raster layers are treated as elements in mathematical expressions
- Analysis of multi-layer or multivariate data (e.g., satellite image processing and analysis)

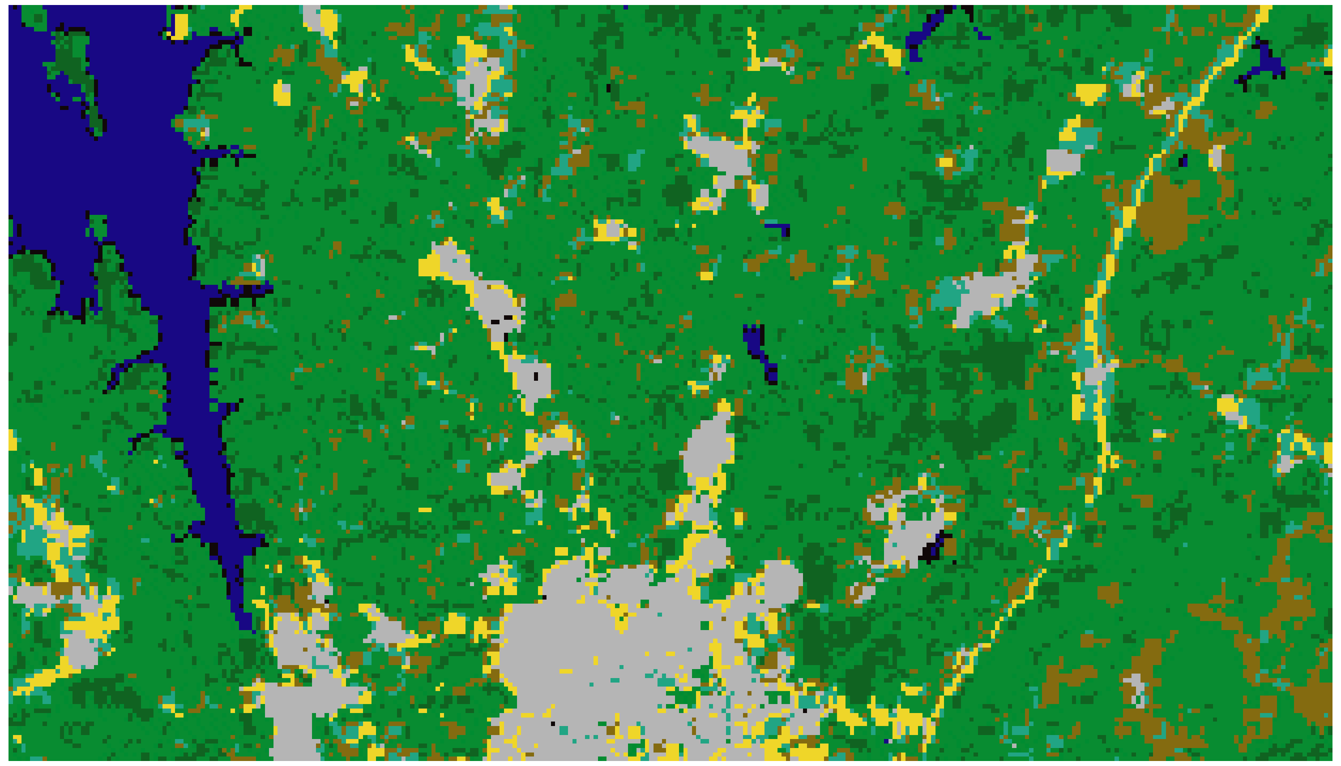
Conversions

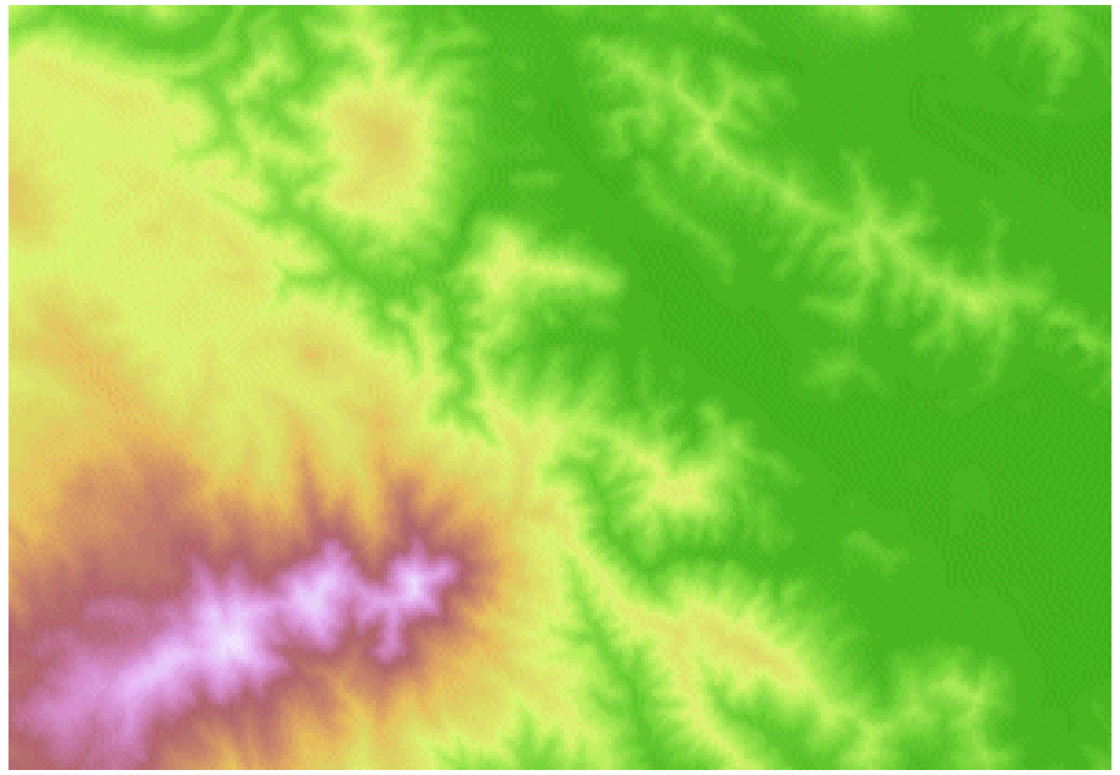
- Raster to vector conversion
- Vector to raster conversion
- Reclassification

Rasters as…

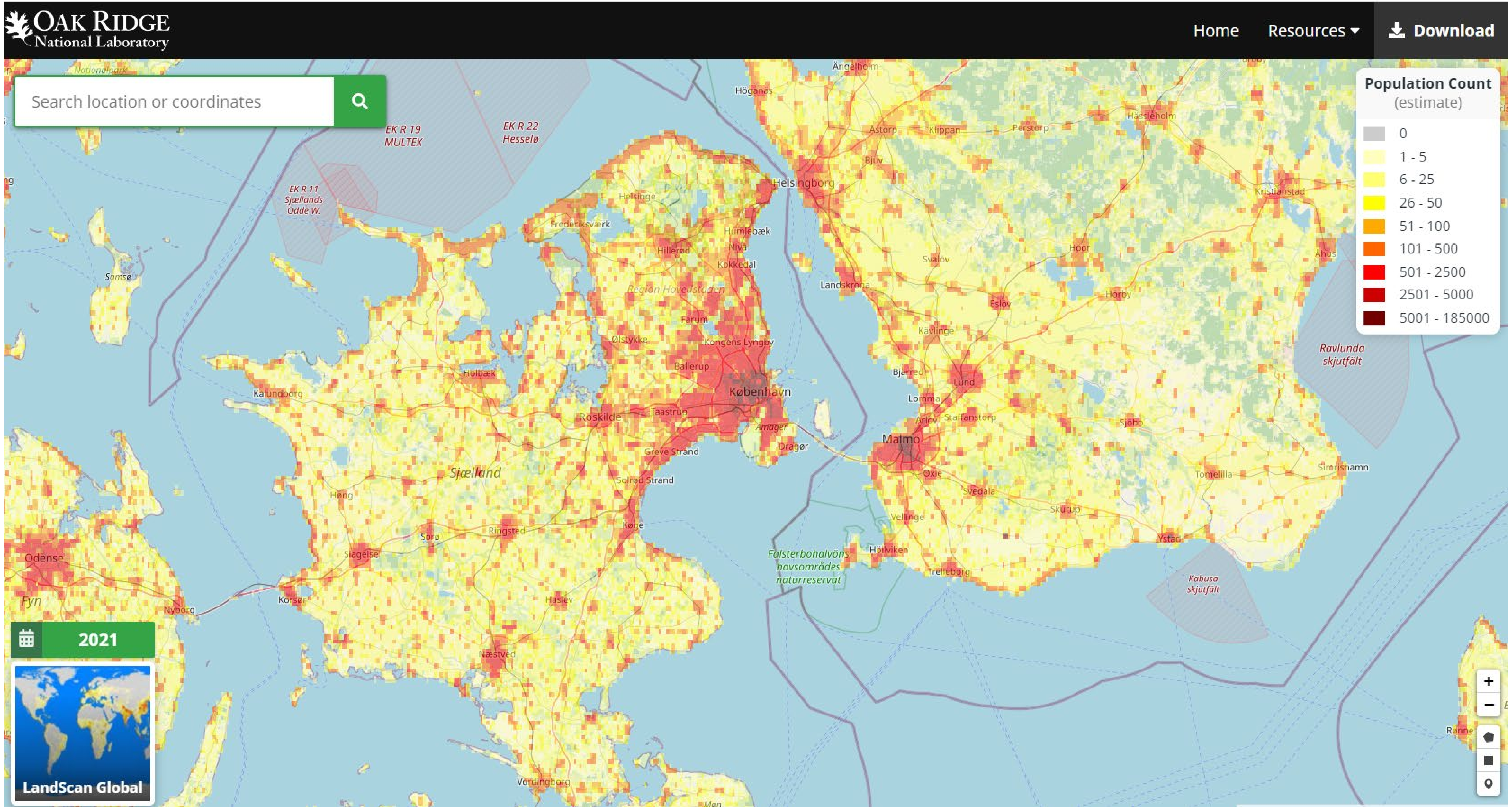
- Basemaps
- Surface Maps
- Thematic Maps
- Attributes of a feature



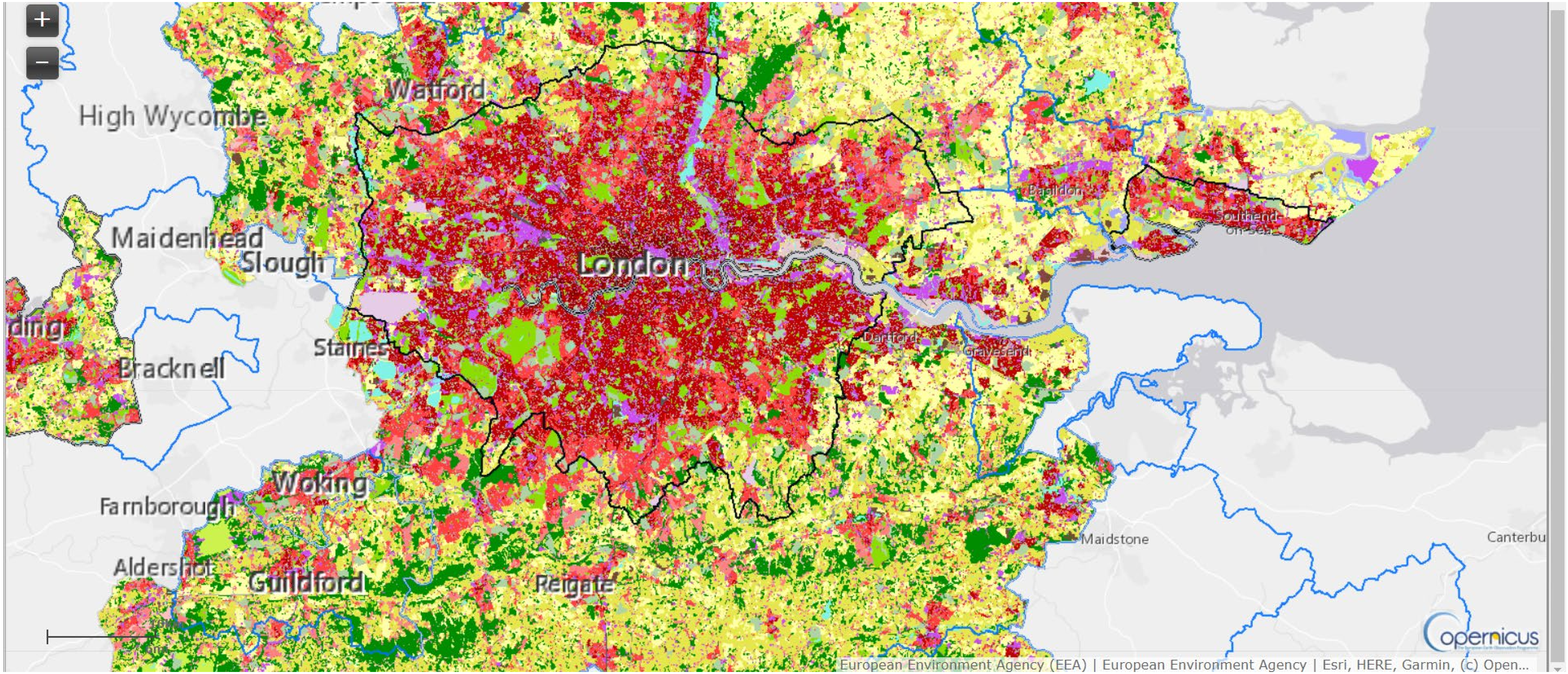




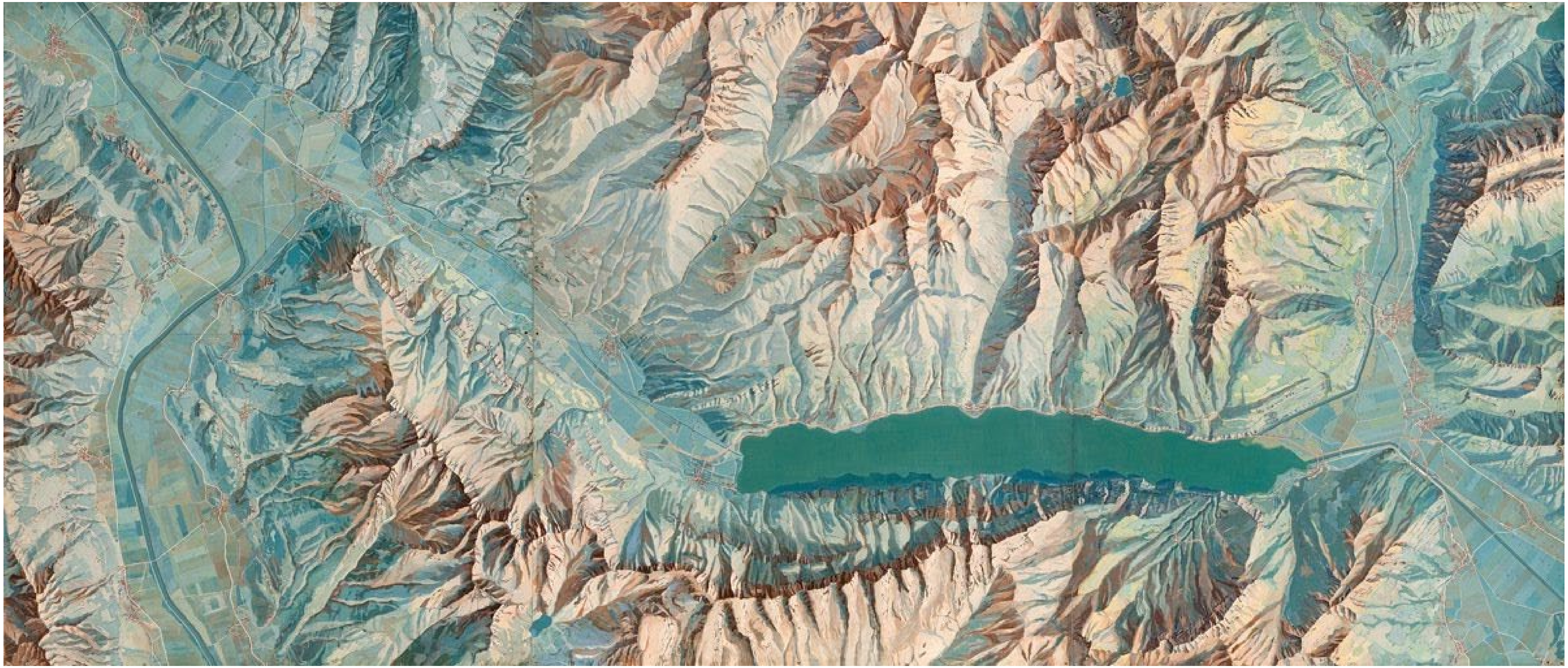
Population density



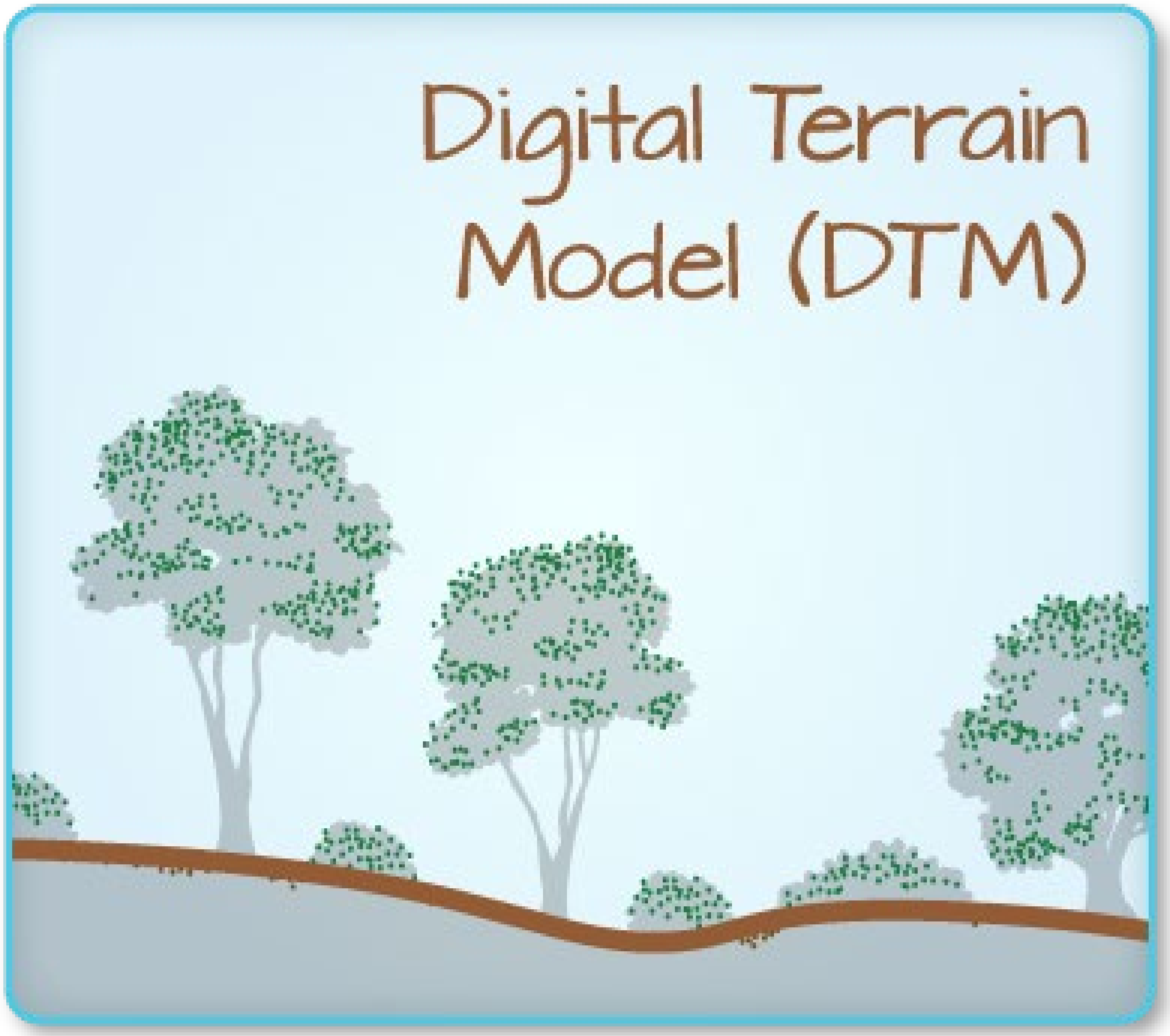
Urban Cover / Urban atlas



Digital Elevation Models (DEMs)



DEM, DTM and DSM...



Wasser, 2018. Leah Wasser. Lesson 4. Create a Canopy Height Model With Lidar Data

Uses of DEMs

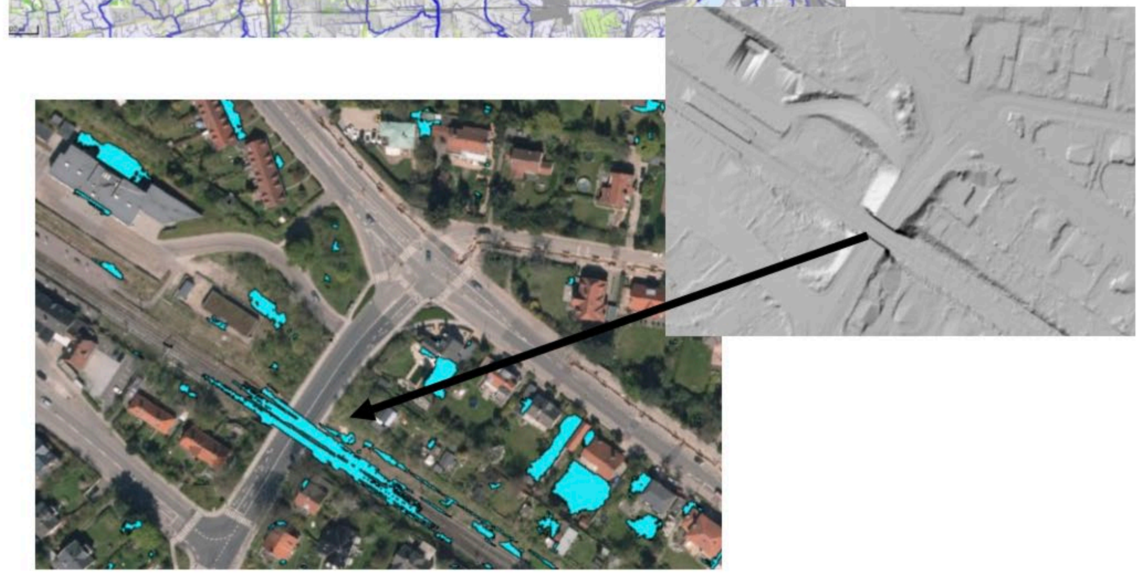
- Determining attributes of terrain (ex. elevation, slope and aspect)
- Finding features on the terrain (ex. drainage basins, watersheds, drainage networks and channels, peaks and pits and other landforms)
- Flood Modelling
- 3D visualizations
- Visibility Analysis

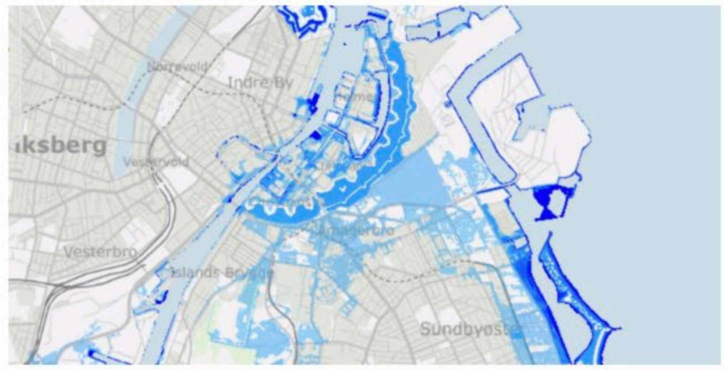
(DEM) - 0,4 m grid

Danish Elevation model
DEM/Point cloud* (2014/15)
DEM/Terrain*
DEM/Surface*

Hydrological elevation models
DEM/Hydrological adjustments*
DEM/Rain*
DEM/Sea rise*

Hydrological products
DEM/Flow
DEM/Seawater on land
DEM/Bluespot extreme rain

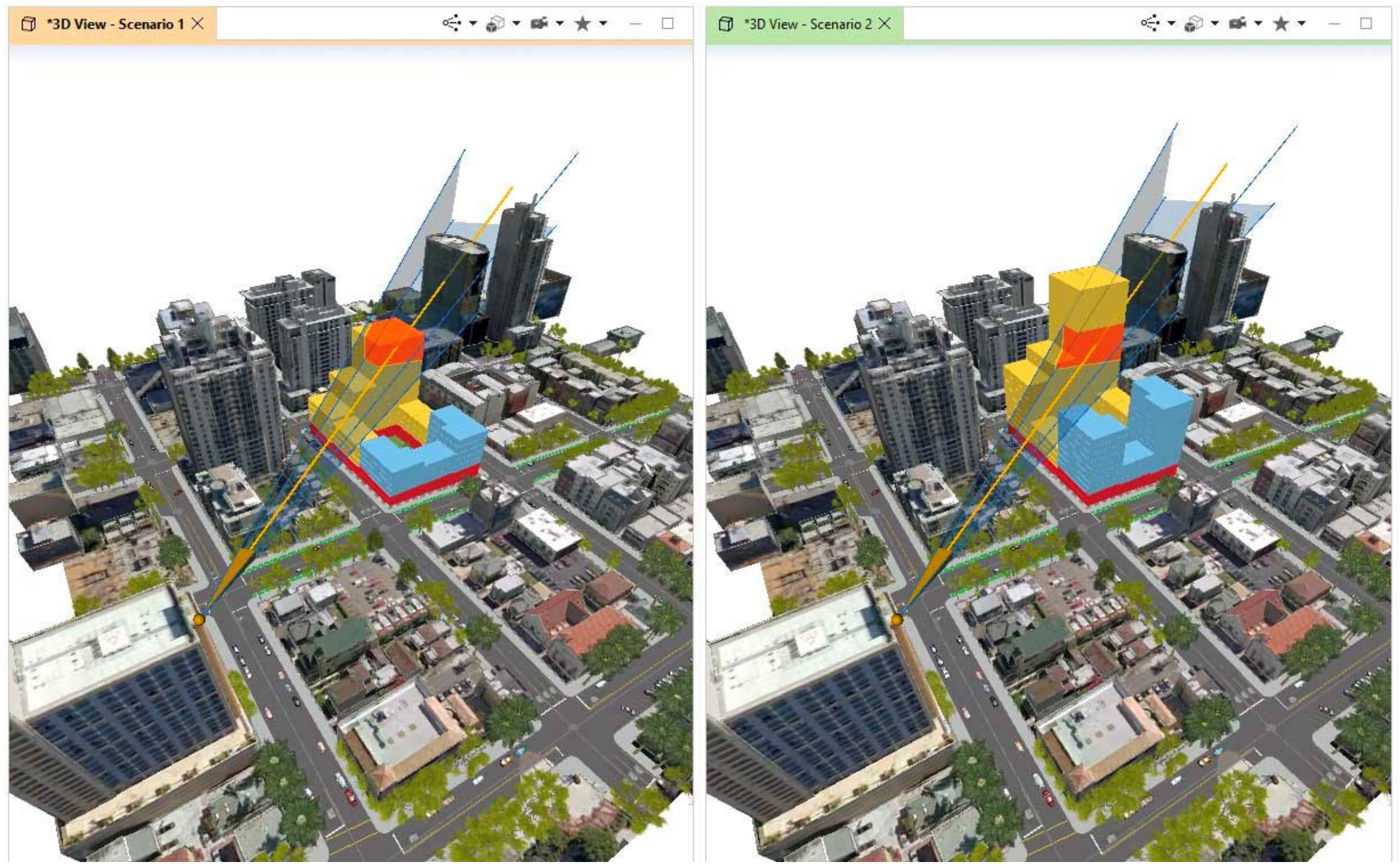




Download at https://download.kortforsyningen.dk/

Uses of DSMs

- Landscape Modelling
- City Modelling
- 3D visualizations
- Visibility Analysis



Some applications

- Find north-facing slopes on a mountain as part of a search for the best slopes for ski runs.

- Calculate the solar illumination for each location as habitat analysis to determine the diversity of life at each site.

- Find all southerly slopes in a mountainous region to identify locations where the snow is likely to melt first as part of a study to identify those residential locations likely to be hit by runoff first.

- Identify areas of flat land to find an area for a plane to land in an emergency.

- Suitability of different farming plans.

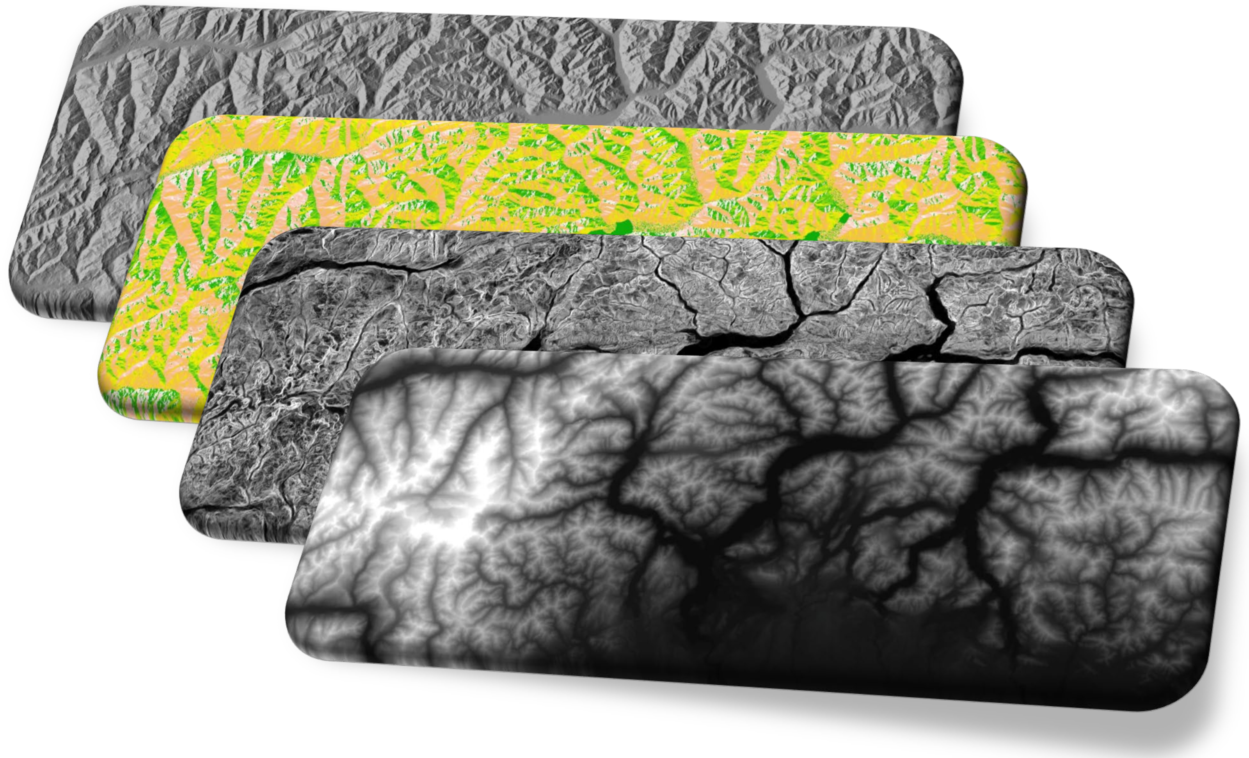
Discuss in groups

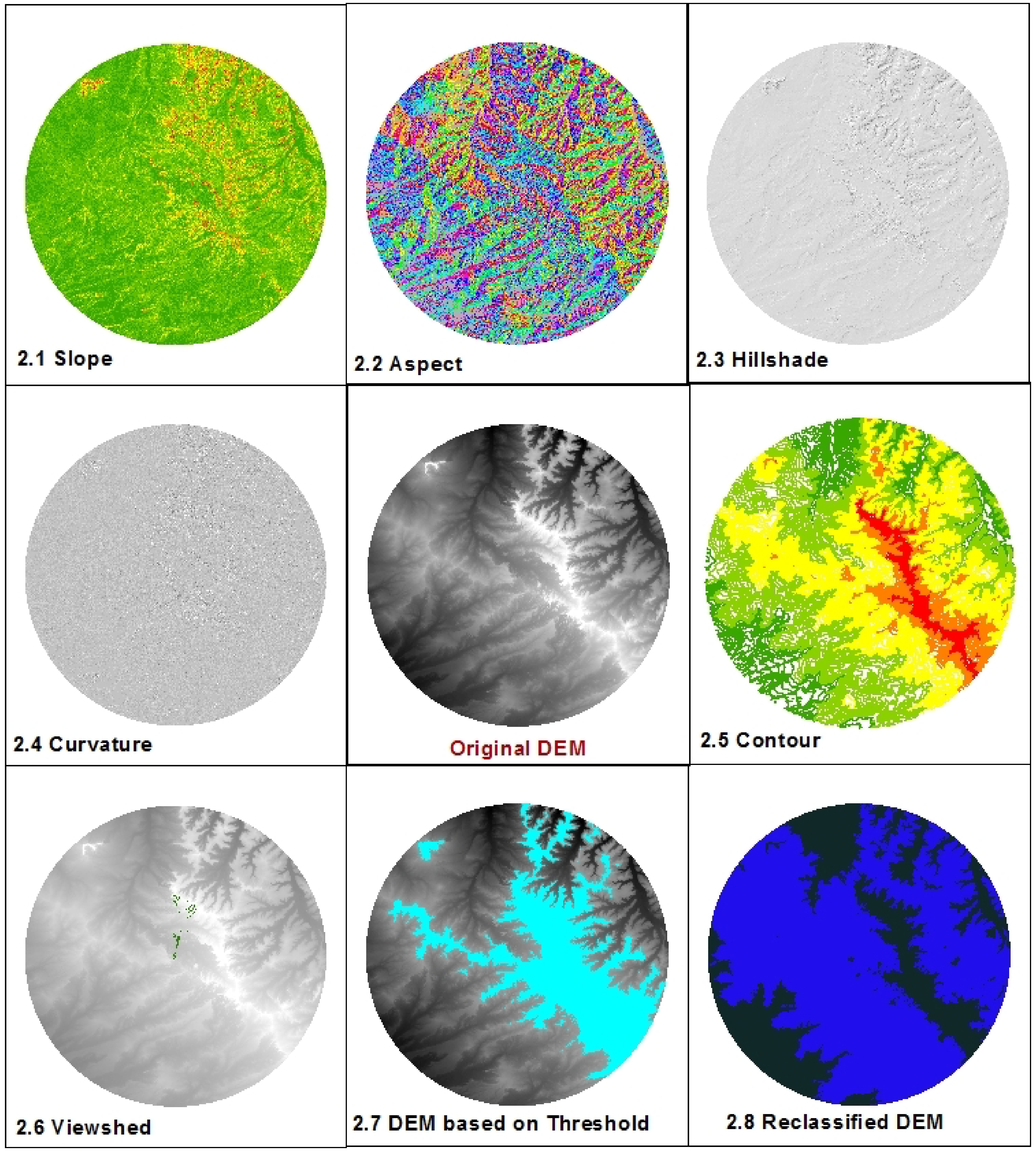
In which situations would you use raster data and in which situations would you use vector data?

Present 2 examples and discuss concerns on spatial and temporal resolution.

How to use DEMs?

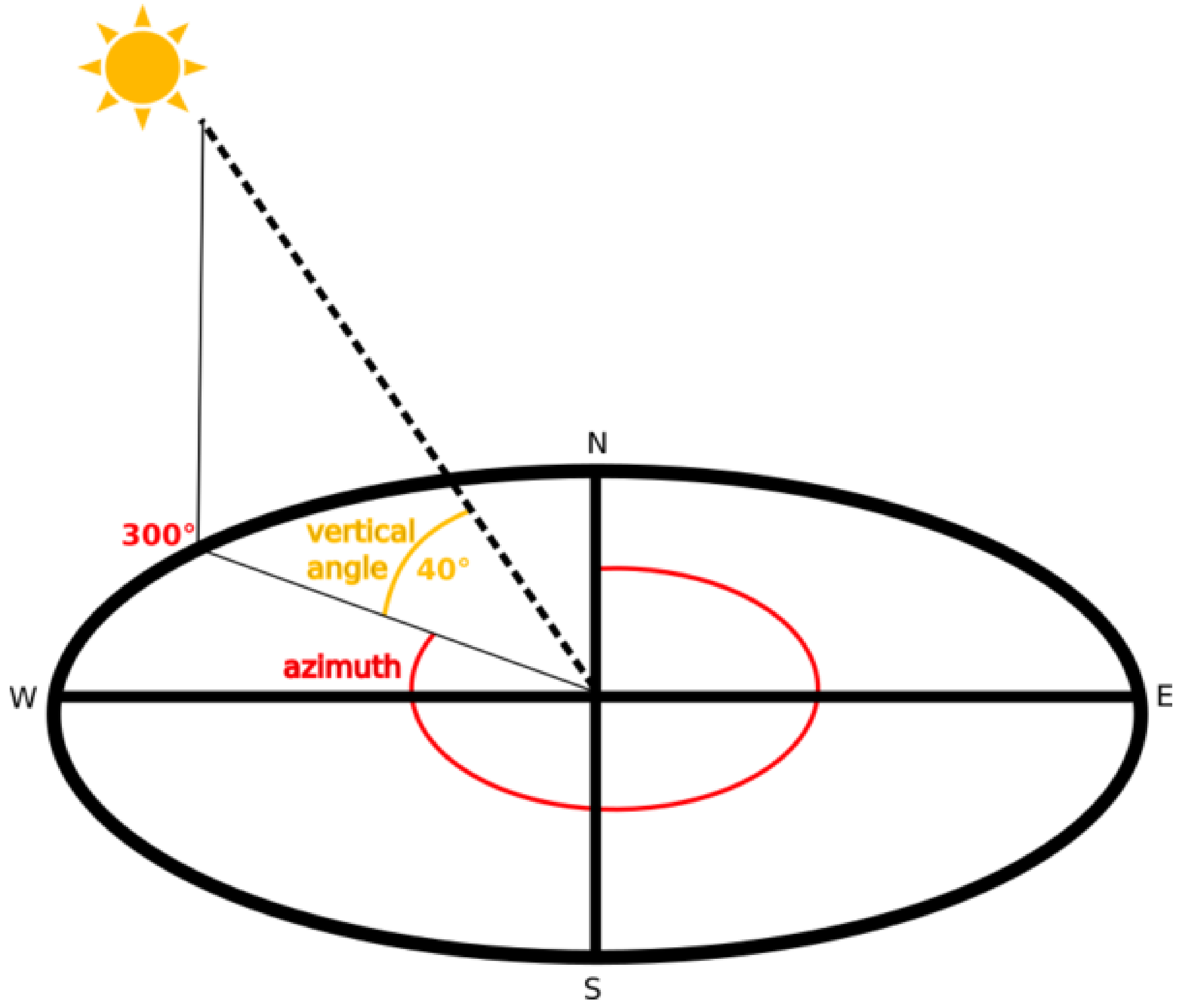
- Slope
- Aspect
- Hillshade
- Viewshed





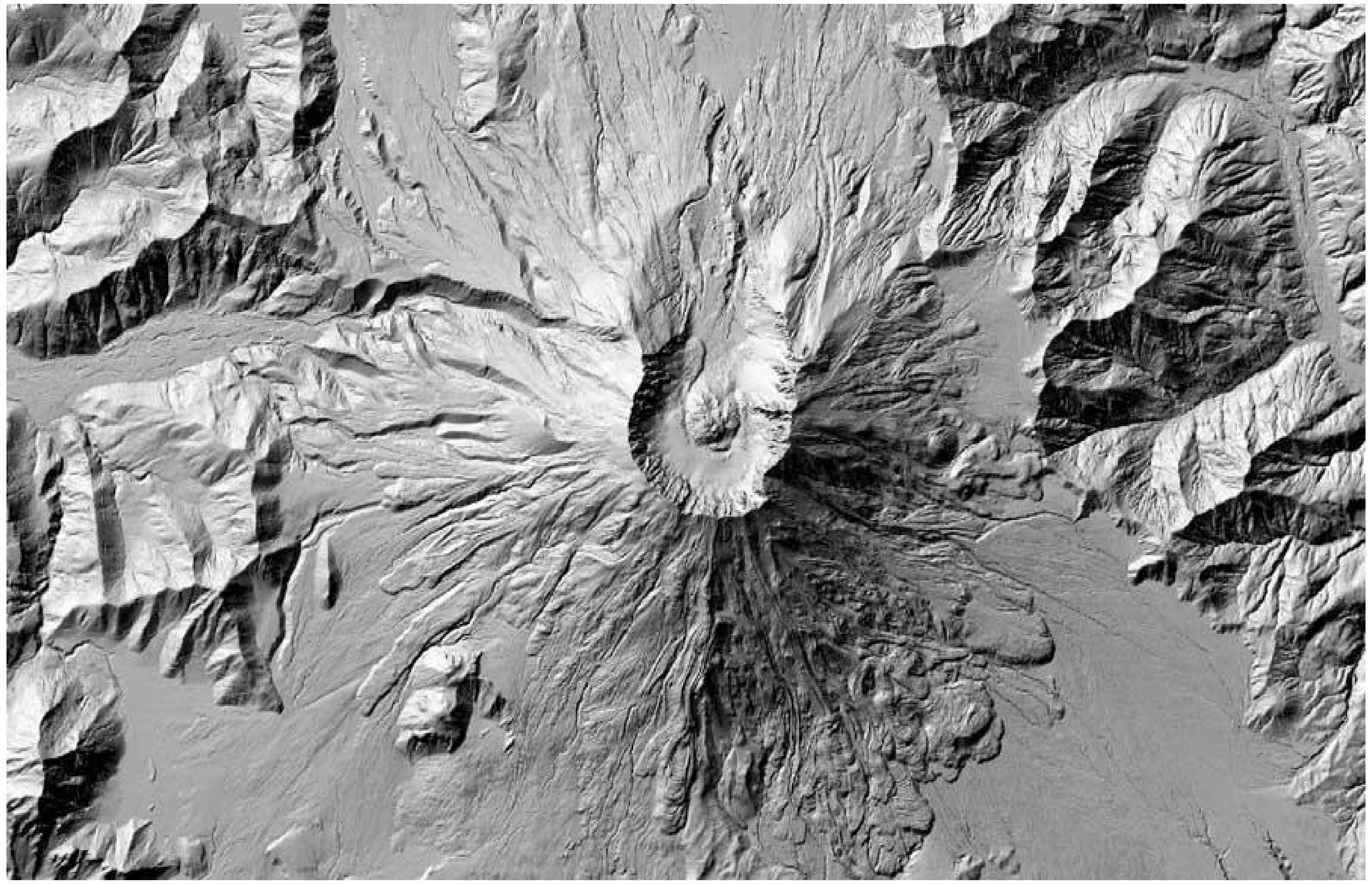
Hillshade

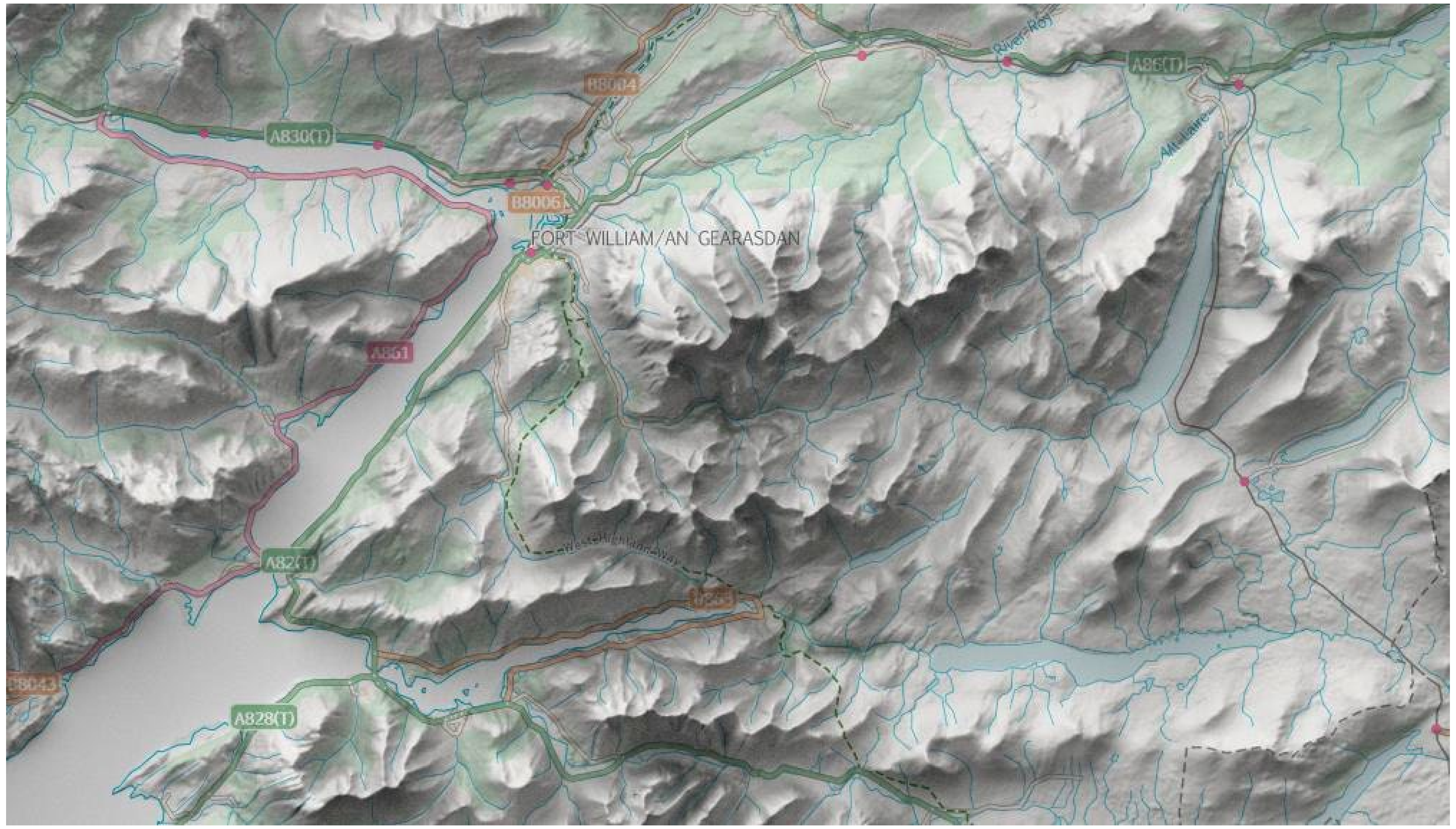
- Setting a hypothetical light source and calculating the illumination values for each cell in relation to neighboring cells.
- It can greatly enhance the visualization of a surface for analysis or graphical display.



Hillshade visualization

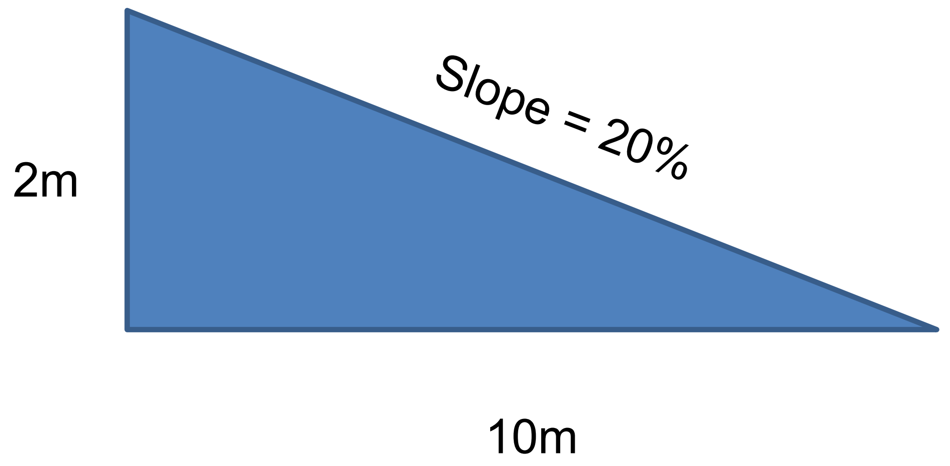
- By placing an elevation raster on top of a hillshade raster and adjusting the transparency of the elevation raster, you can easily create a visually appealing relief map of a landscape.

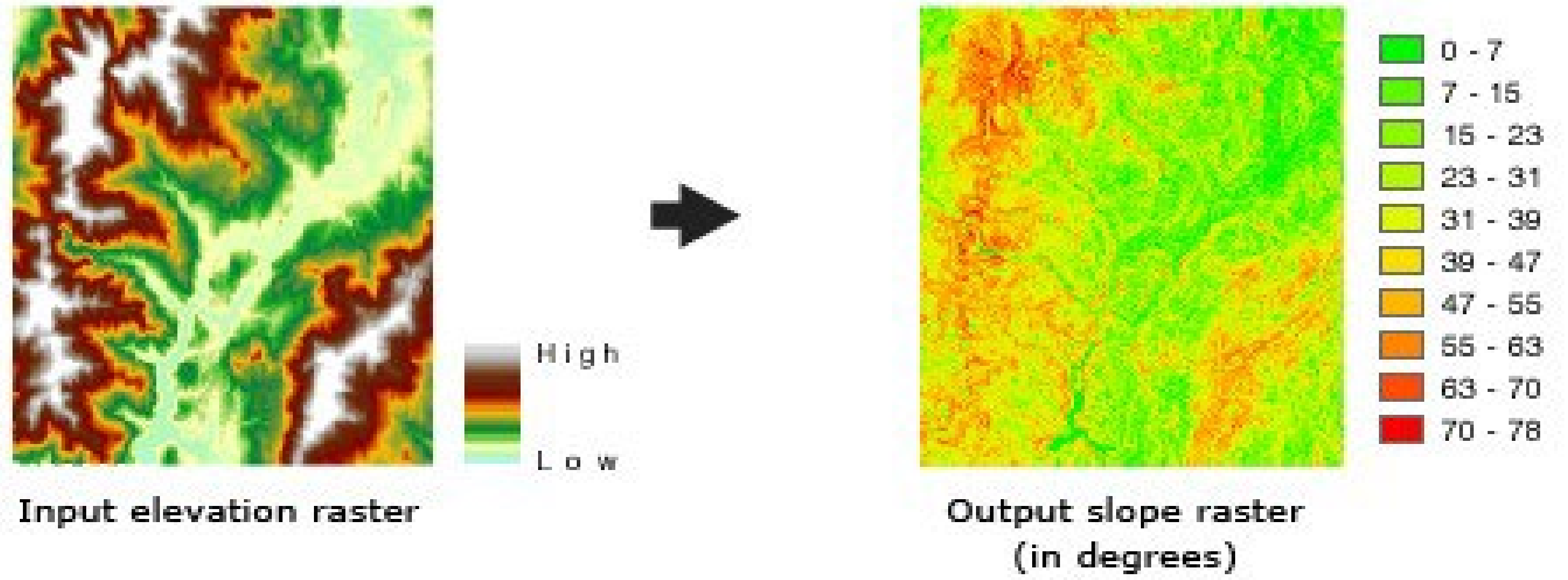


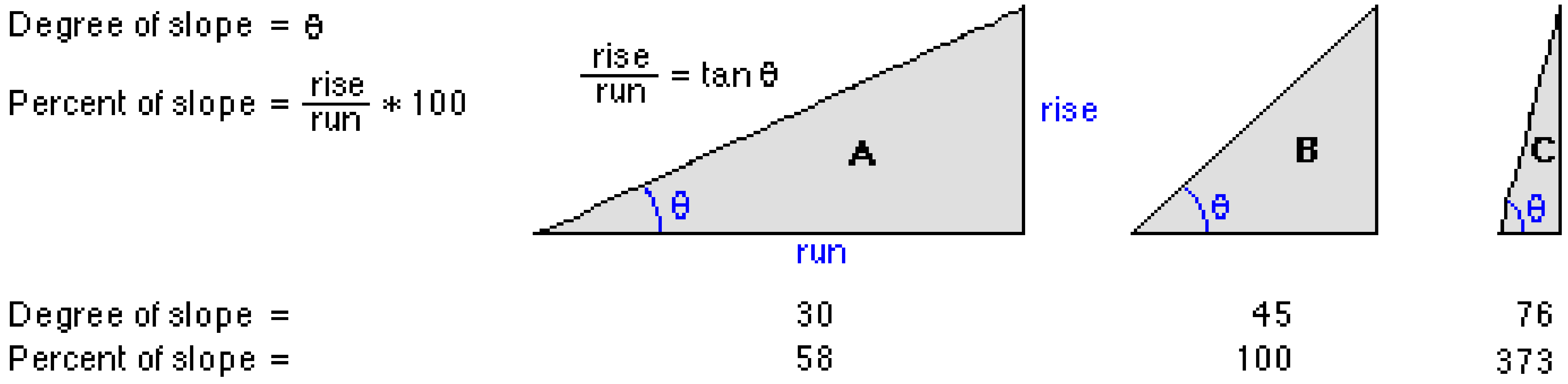


Slope

- Change in elevation
- ↑ slope → the steeper
- Angle of inclination to the horizontal

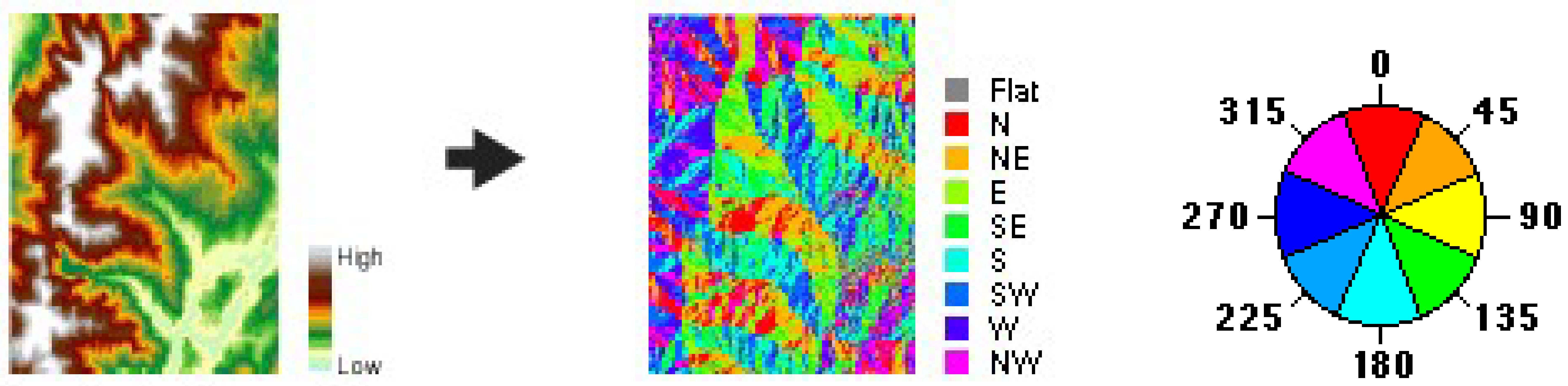






Aspect

- Aspect identifies the downslope direction of the maximum rate of change in value from each cell to its neighbors.
- Simply slope direction
- The values of each cell in the output raster indicate the compass direction that the surface faces at that location.
- Measured clockwise in degrees from 0 (due north) to 360 (again due north), coming full circle.
- Flat areas having no downslope direction are given a value of -1.



Input elevation raster

Output aspect raster

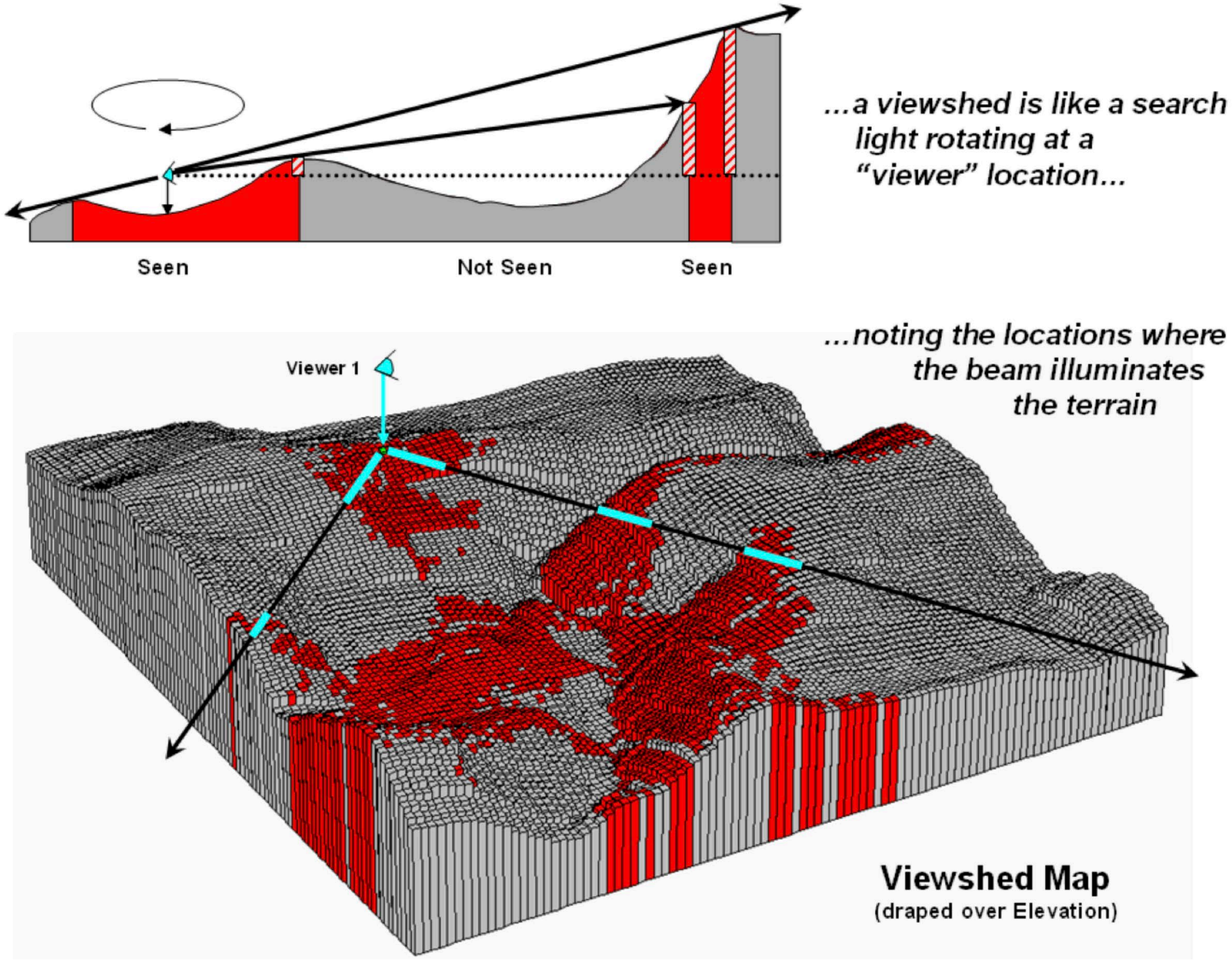
Practically, in python …

```
from osgeo import gdal
for f in ['slope', 'aspect', 'hillshade']:

    outfile = "dtm_"+f+".tif"
    gdal.DEMProcessing(outfile, "./data/dtm.tif", f);

    with rasterio.open(outfile) as dataset:
        dem=dataset.read(1, masked=True)
        plt.figure(figsize=(15, 15))
        imgplot = plt.imshow(dem, cmap='gray’)
```

*If you want to dig into it, take a look at the tutorial

Viewshed analysis

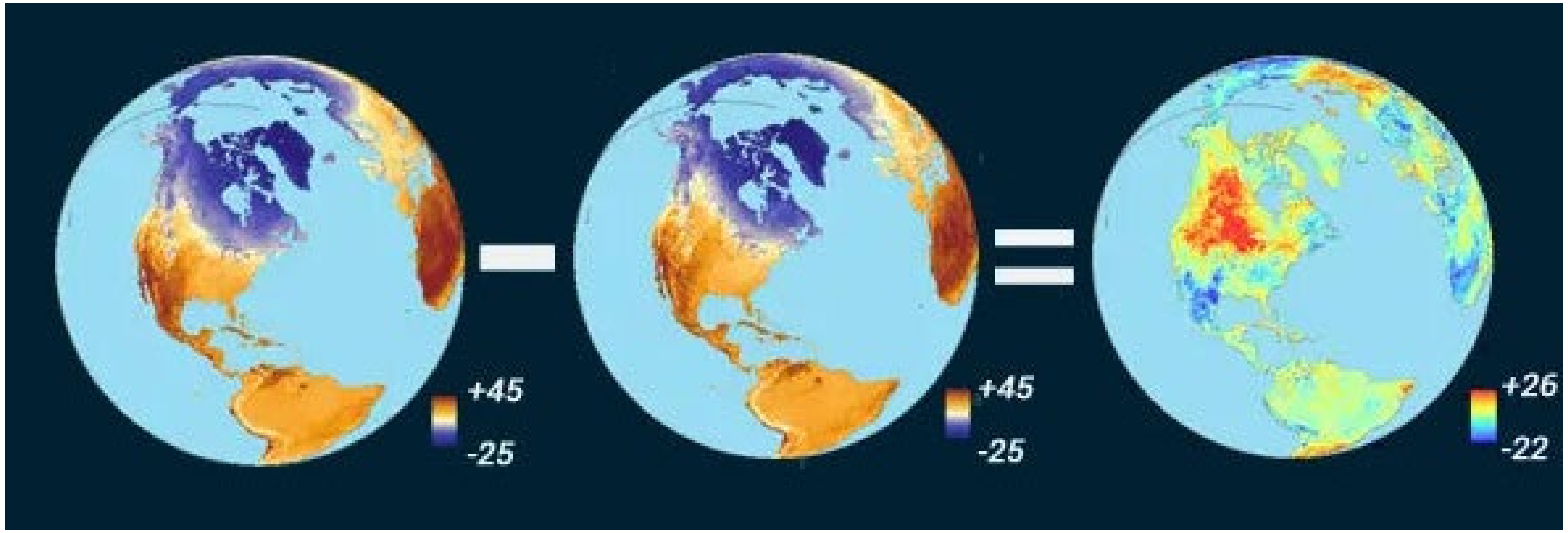
- Identifies the cells in an input raster that can be seen from one or more observation locations.
- If you have only one observer point, each cell that can see that observer point is given a value of 1, otherwise 0.
- The observer points feature class can contain points or lines.
- It is useful for finding the visibility (finding well-exposed places for communication towers)



Map Algebra

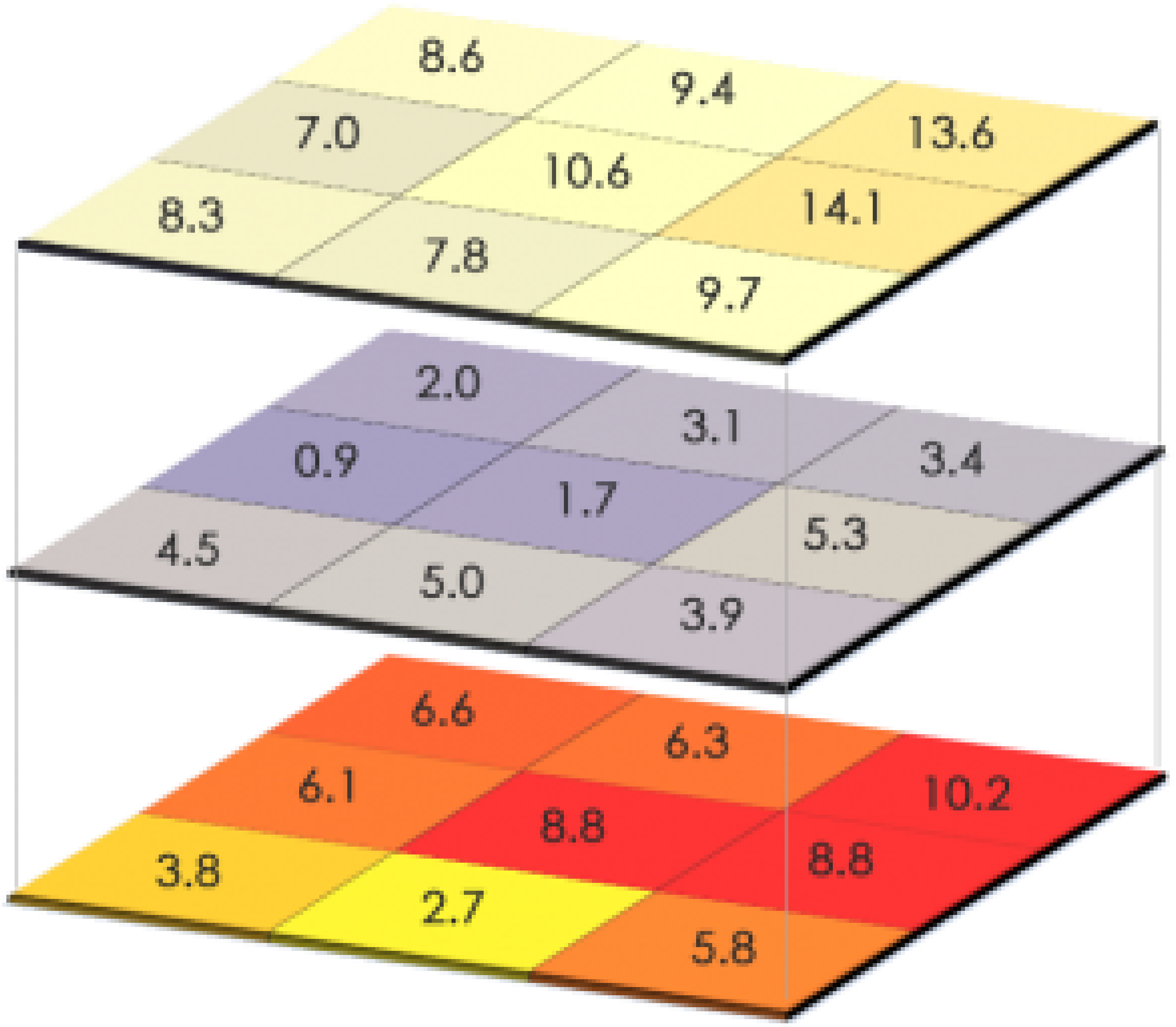
- Primitive calculations to process and analyze raster maps

- Developed by Charles Dana Tomlin in the 1980s
- 4 types of primitive operations that can be combined to form more complex calculations



Types of Map Algebra

- Local
- Focal
- Zonal
- Global

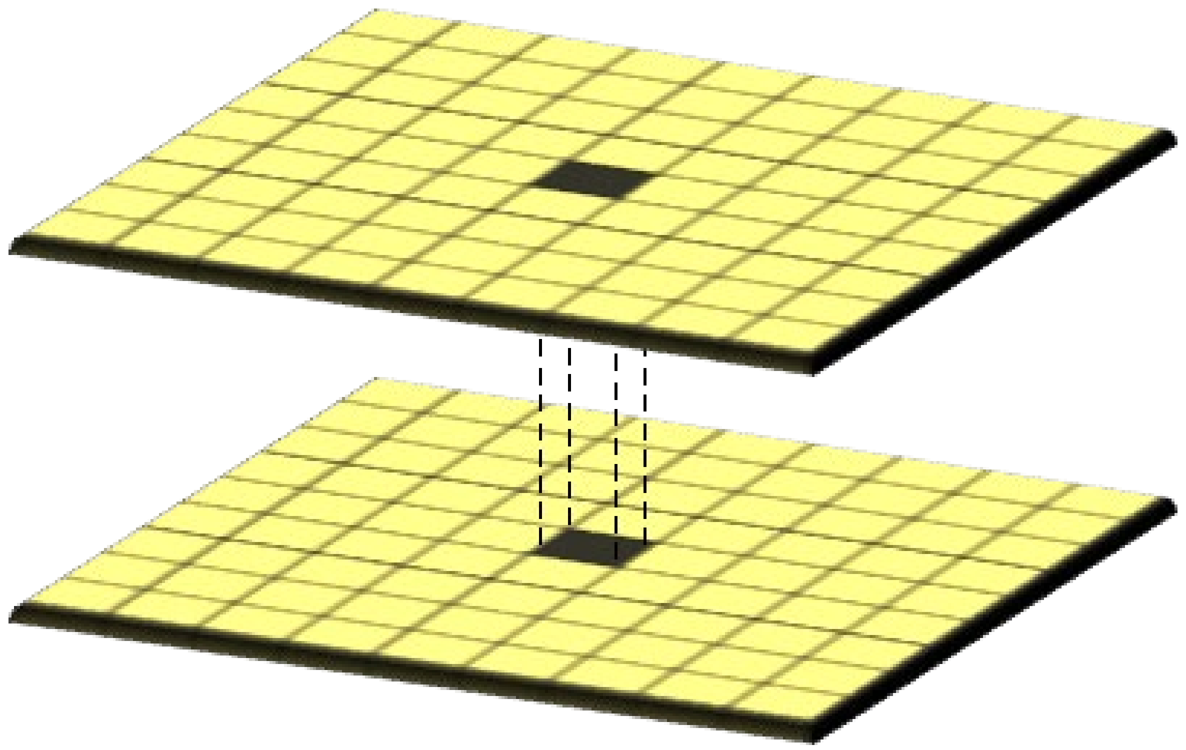


https://gisgeography.com/map-algebra-global-zonal-focal-local/

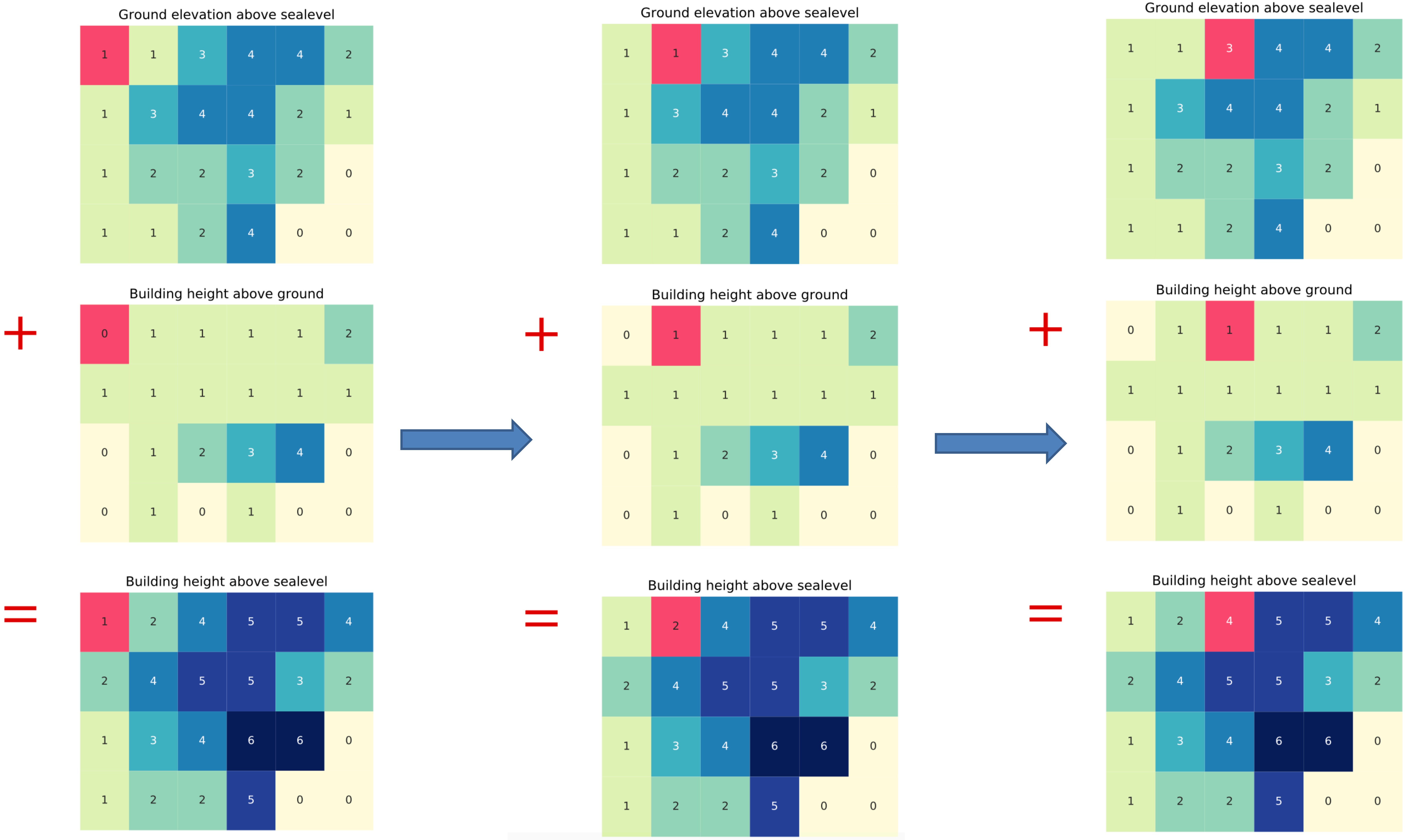
1. Local operations

- Work on individual raster cells
- Cell values in the output raster are calculated based on the values of the same cell in two or more input rasters
- Neighboring cells do not affect the calculations

$$\begin{bmatrix} 1 & 4 & 5 \\ 5 & 3 & 2 \\ 2 & 5 & 2 \end{bmatrix} + \begin{bmatrix} 5 & 1 & 3 \\ 1 & 2 & 1 \\ 1 & 4 & 2 \end{bmatrix} = \begin{bmatrix} 6 & 5 & 8 \\ 6 & 5 & 3 \\ 3 & 9 & 4 \end{bmatrix}$$



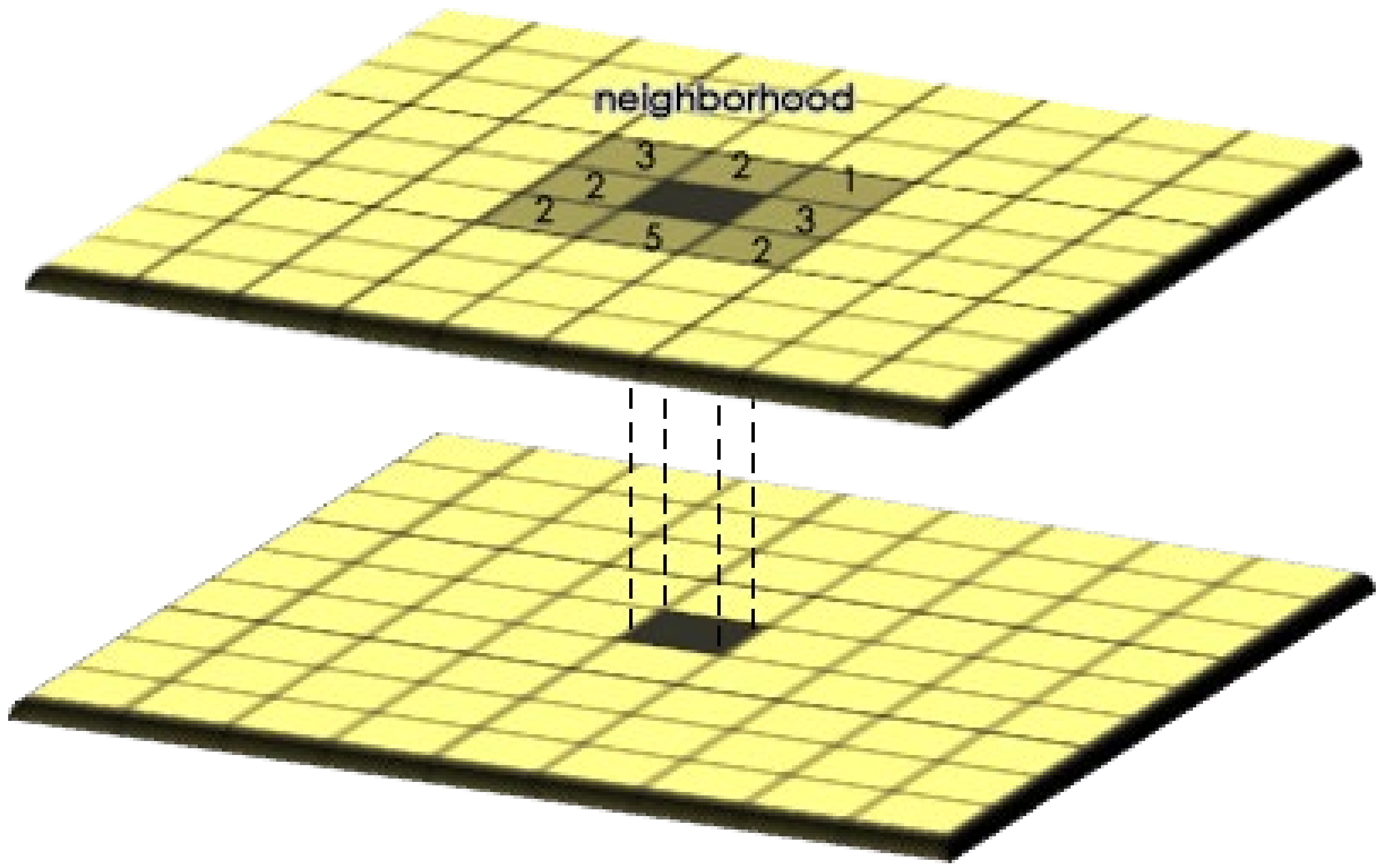
1. Local operations

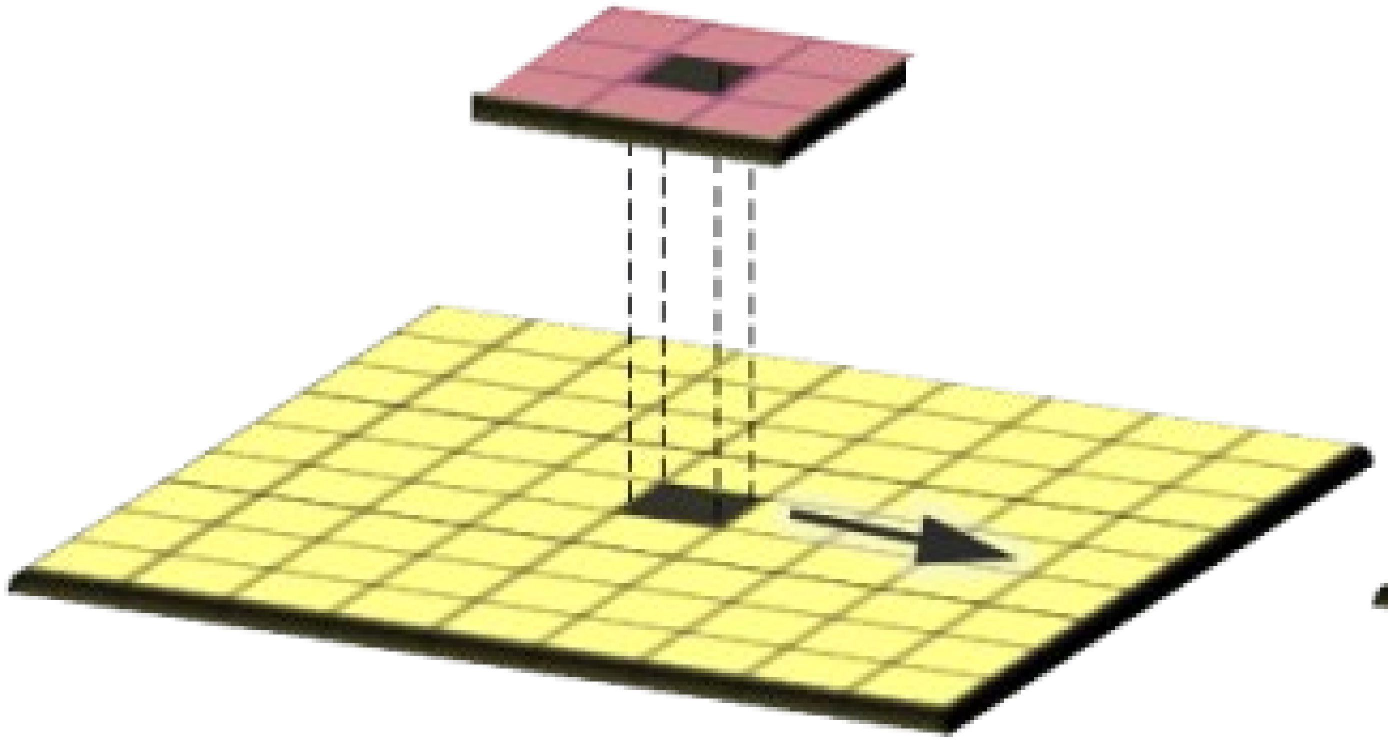


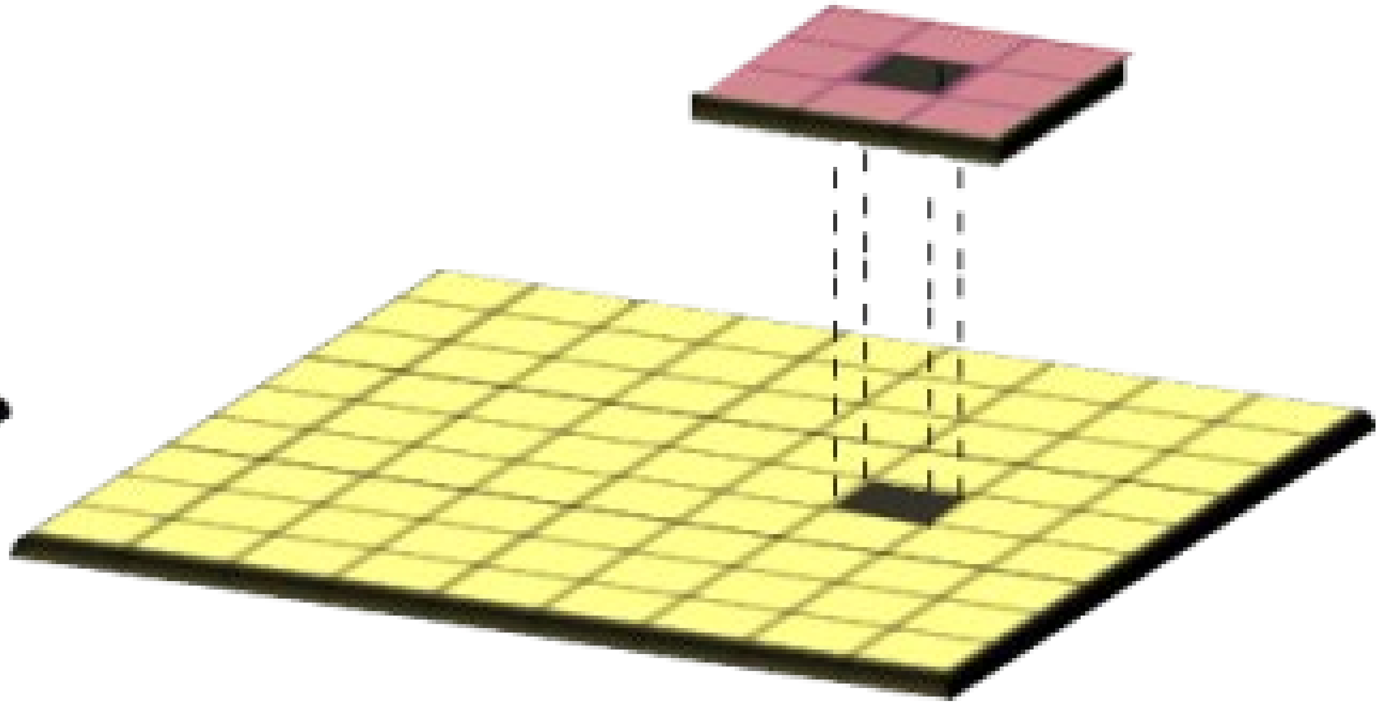
2. Focal operations

- "Neighborhood operations"
- Work on cells and their neighbors
- A kernel/filter does something

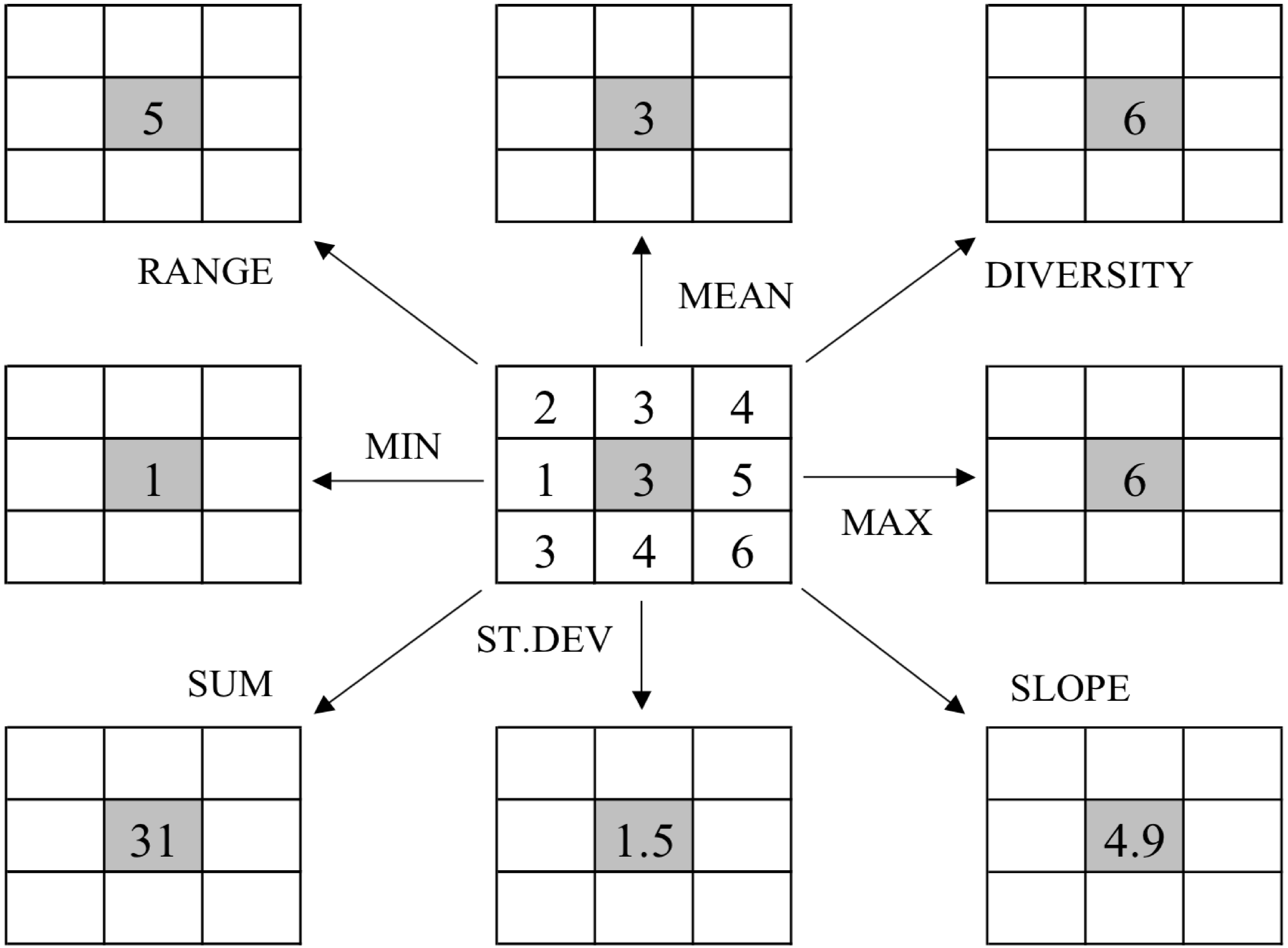
- Cells in the output raster are calculated based on the application of the kernel on the input raster



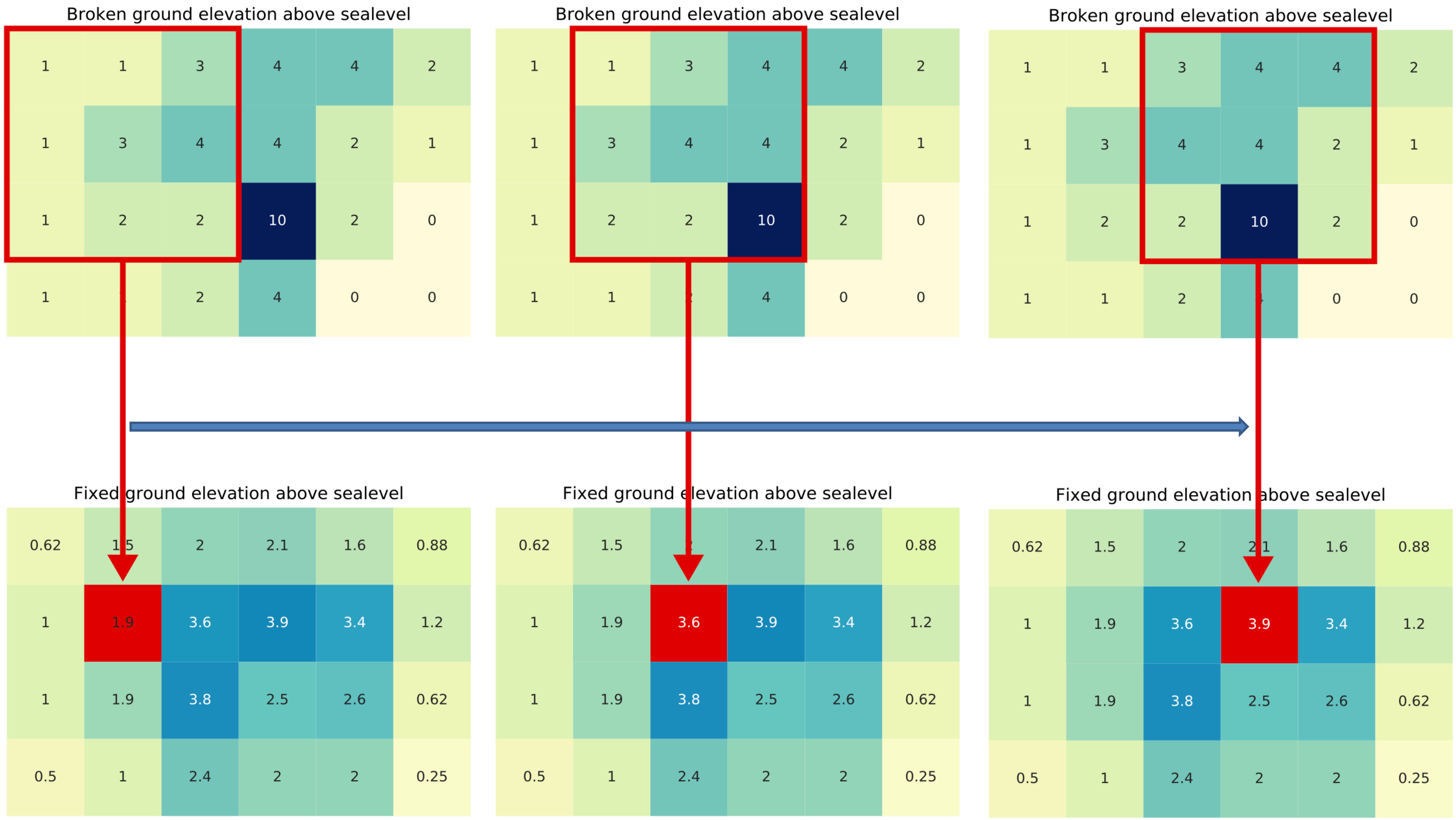




2. Focal operations



2. Focal operations



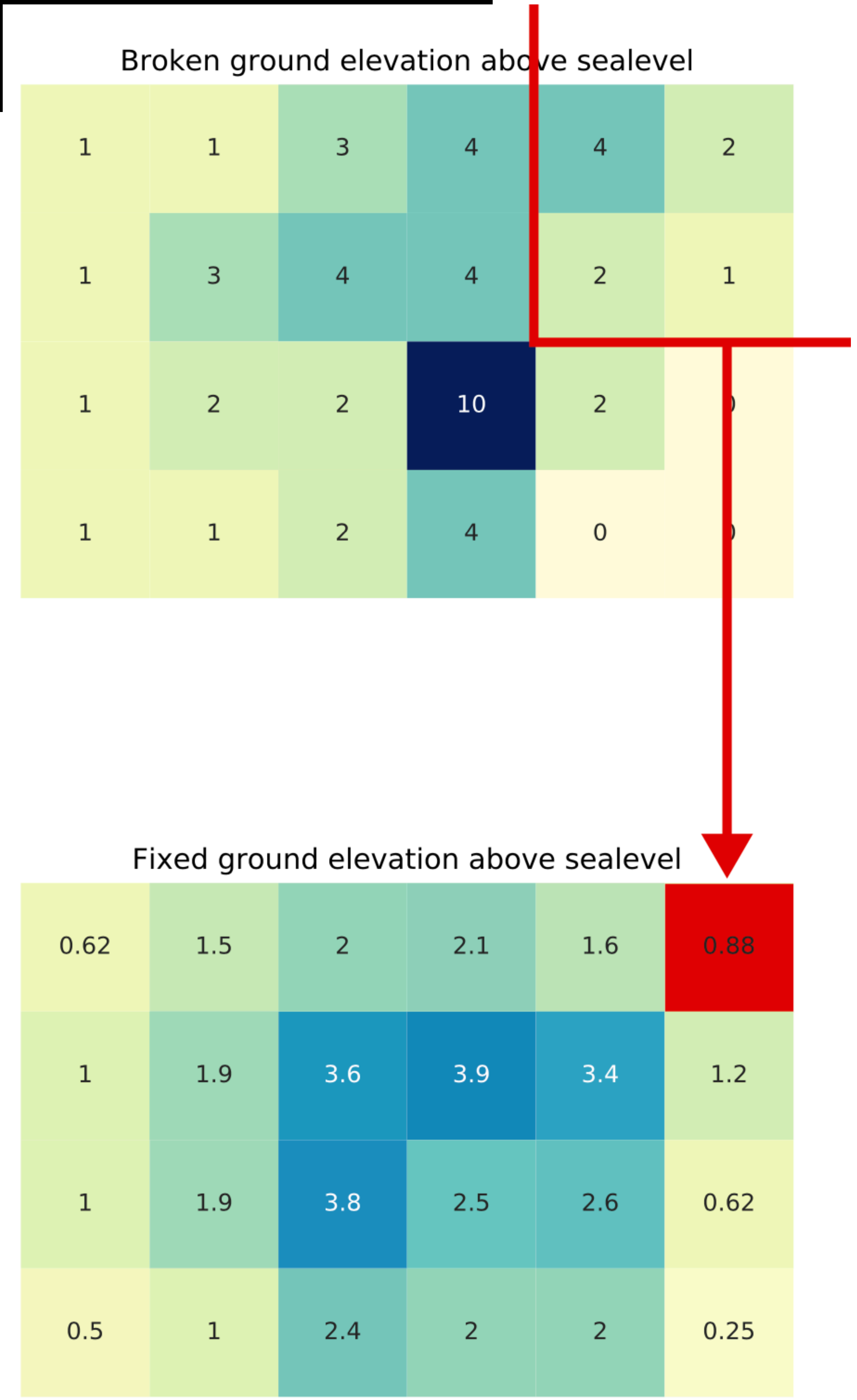
2. Focal operations

- "*Neighborhood operations*"

- Work on cells and their neighbors
- A kernel/filter does something

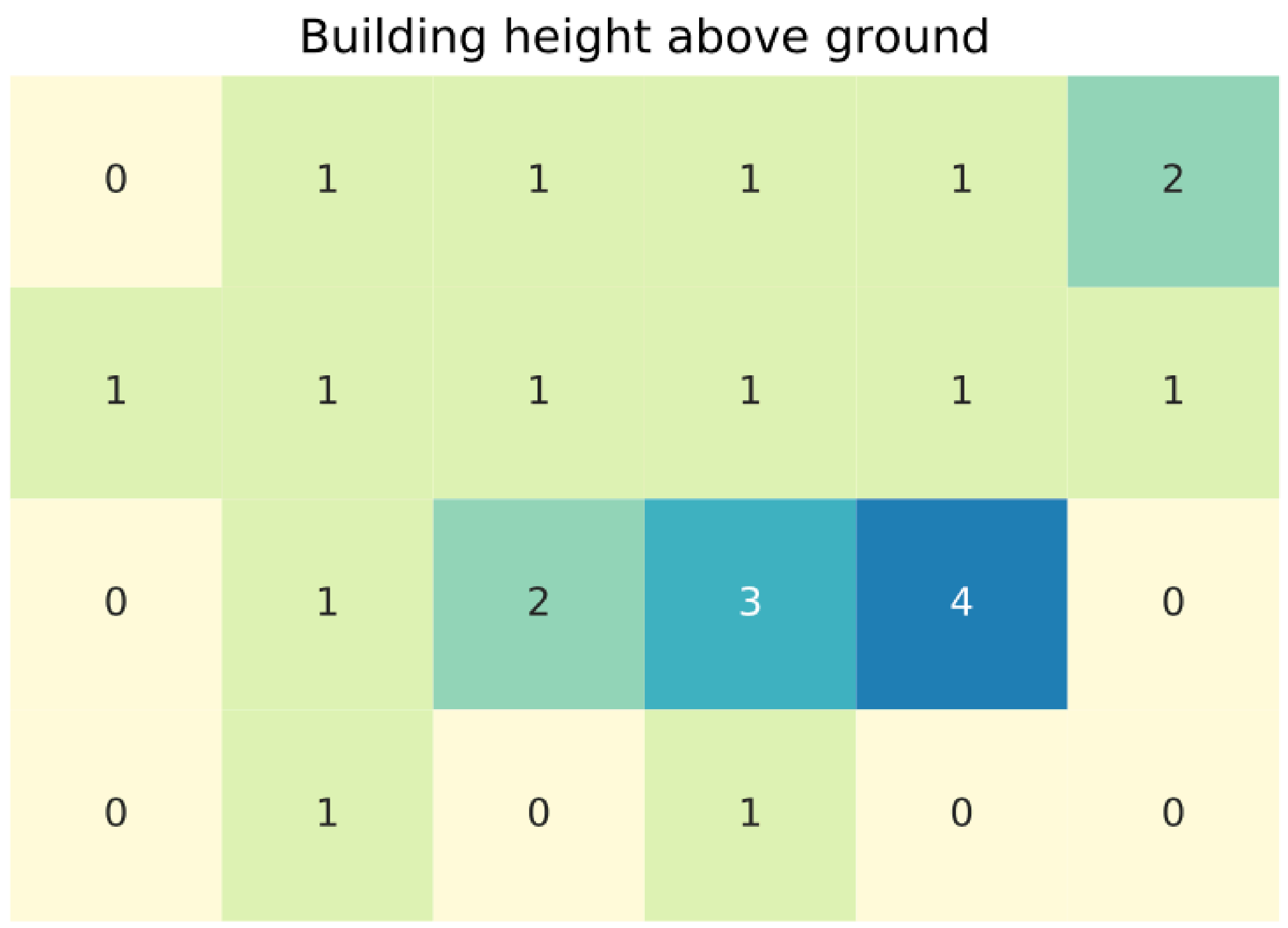
- Cells in the output raster are calculated based on the application of the kernel on the input raster

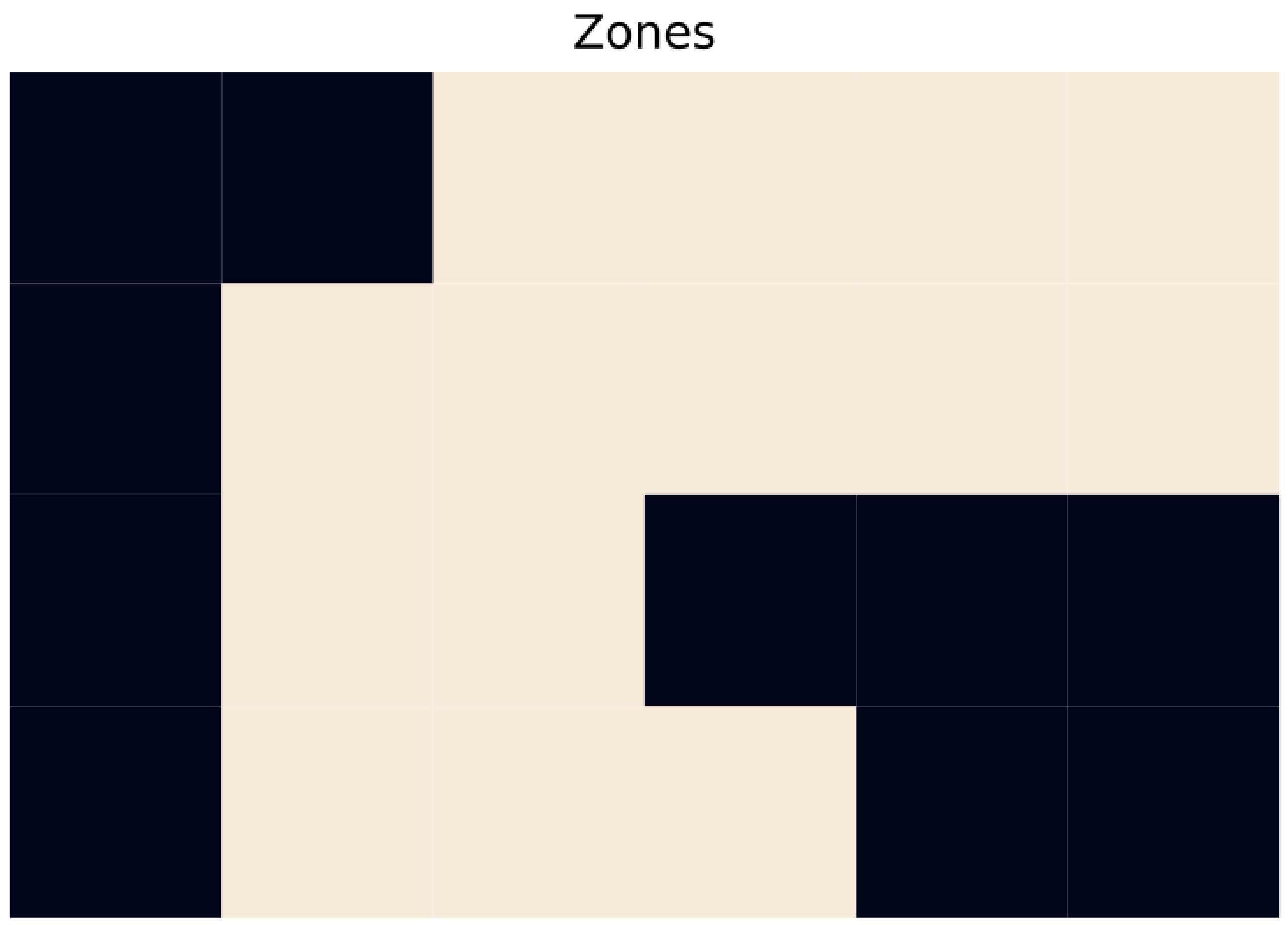
- Edge effect



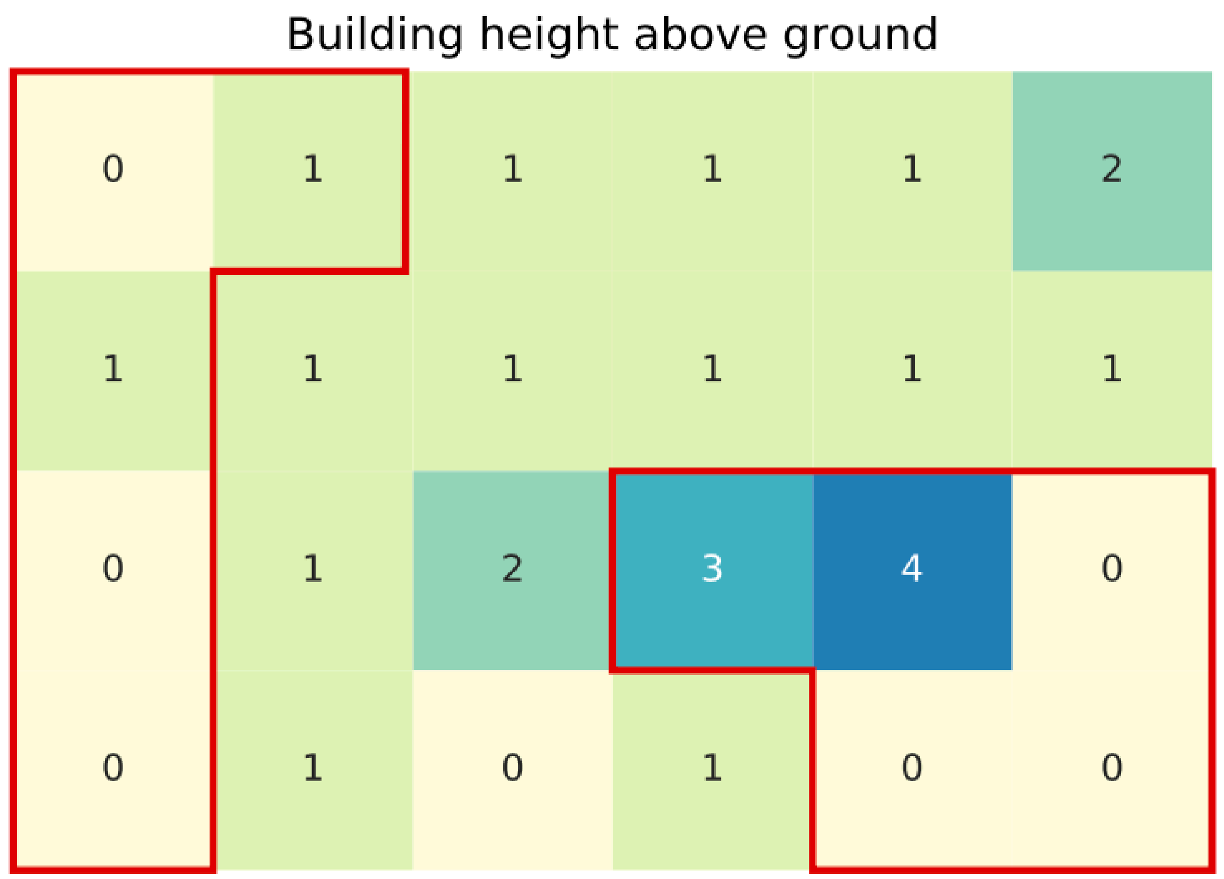
3. Zonal Operations

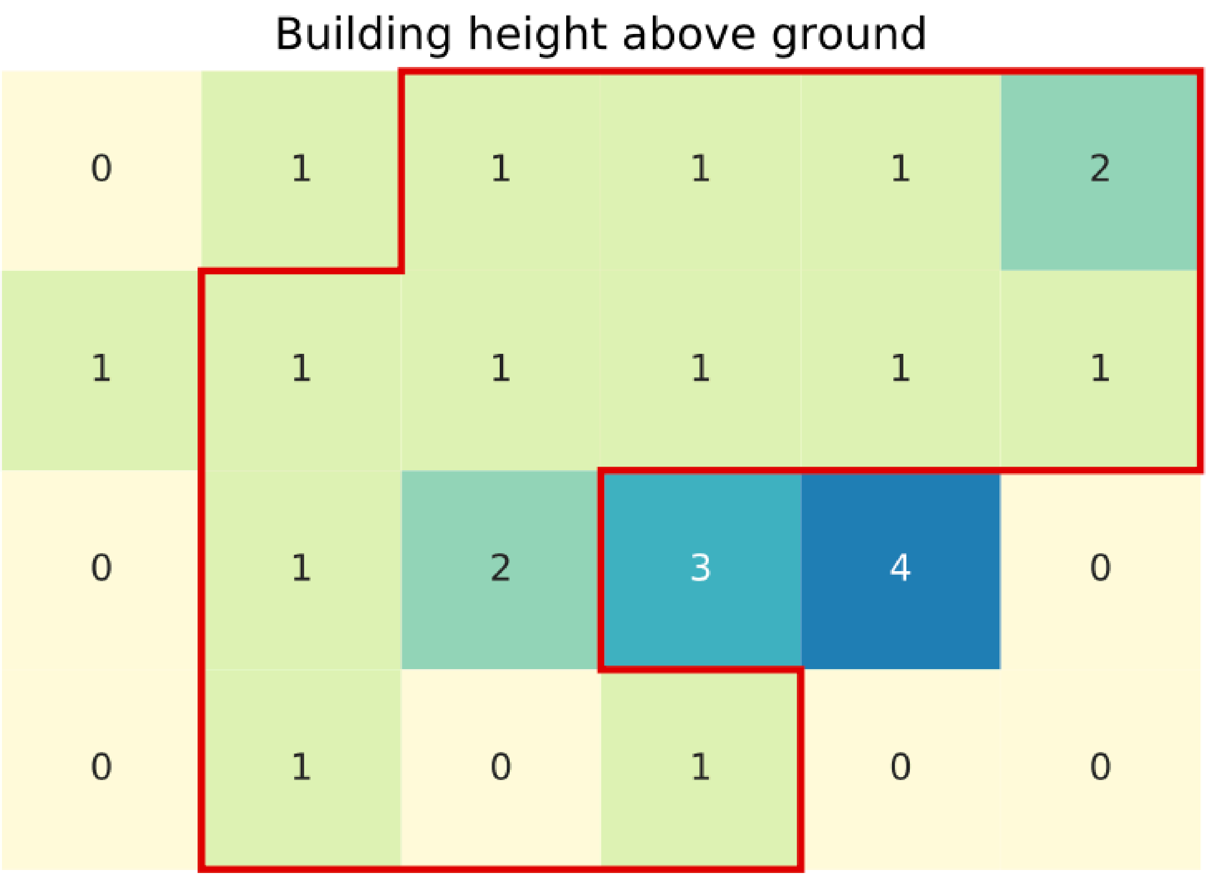
- Work on cells within a zone
- Cells in the output raster are calculated based on the cells within the same zone in the input raster
- Zones do not have to be contiguous

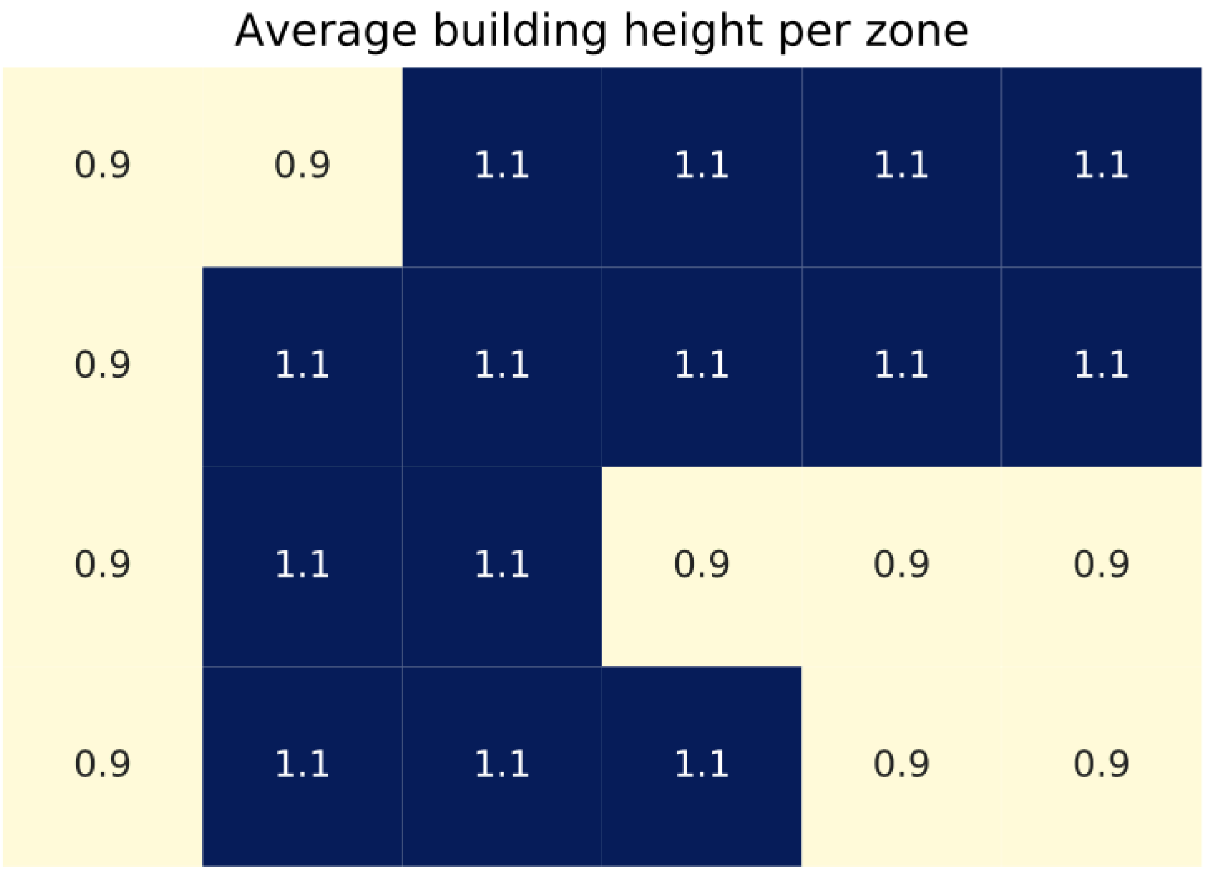


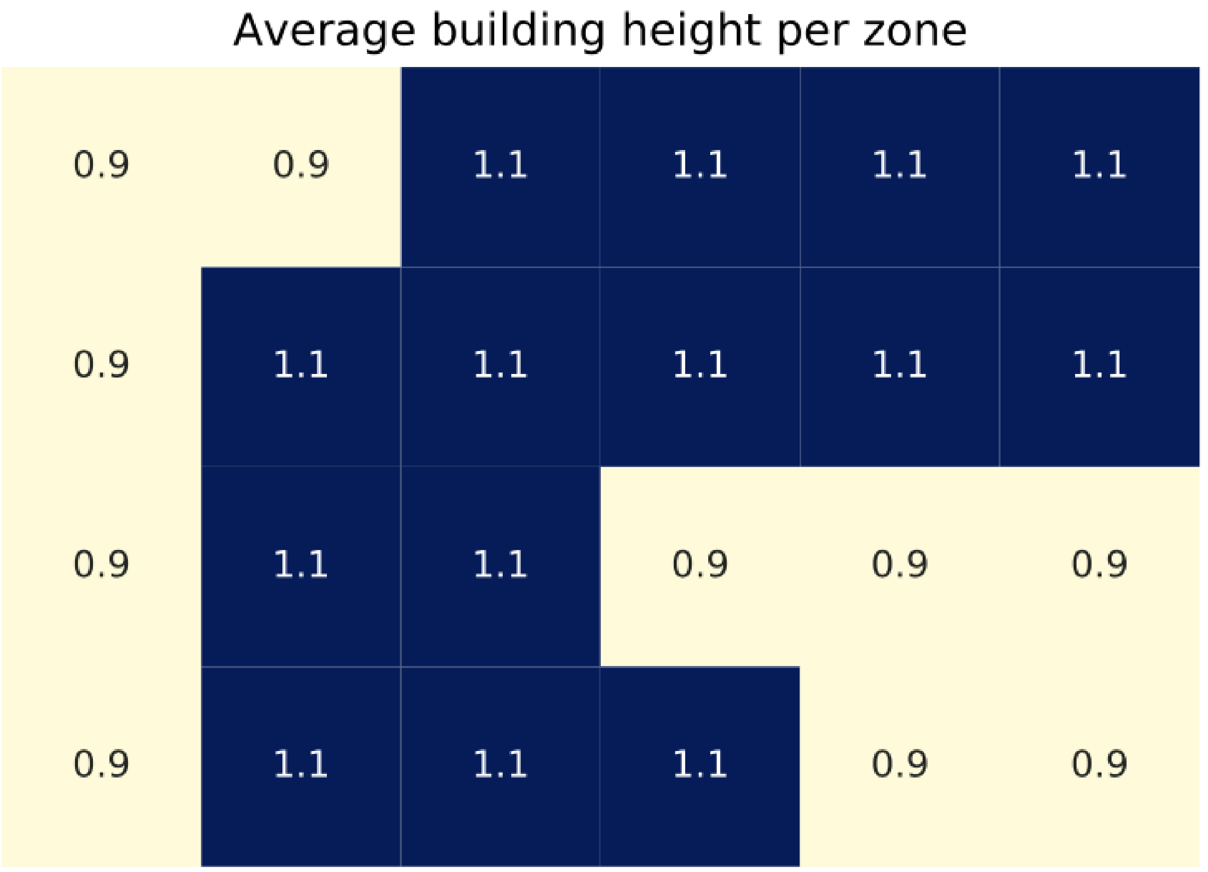


3. Zonal Operations

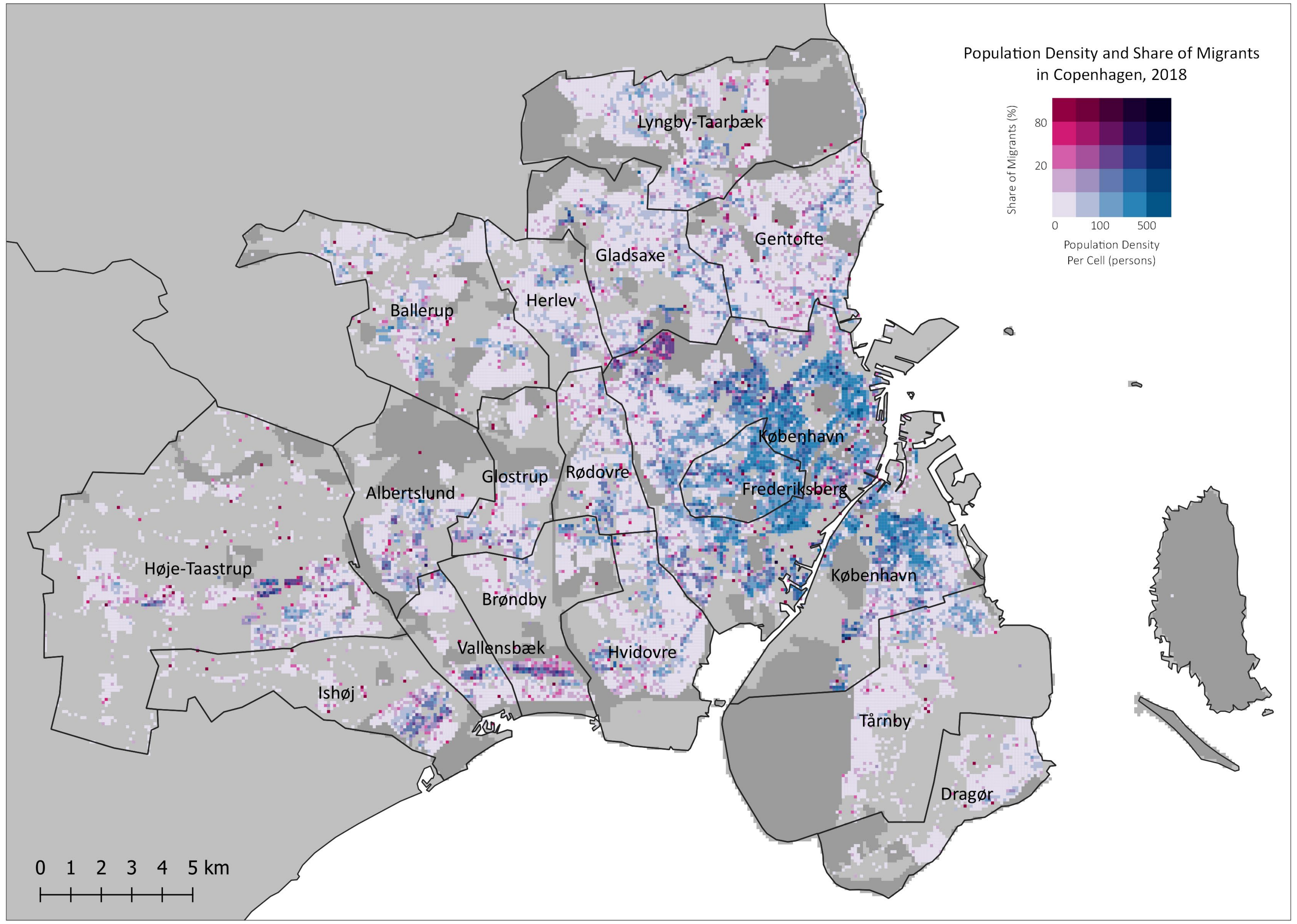


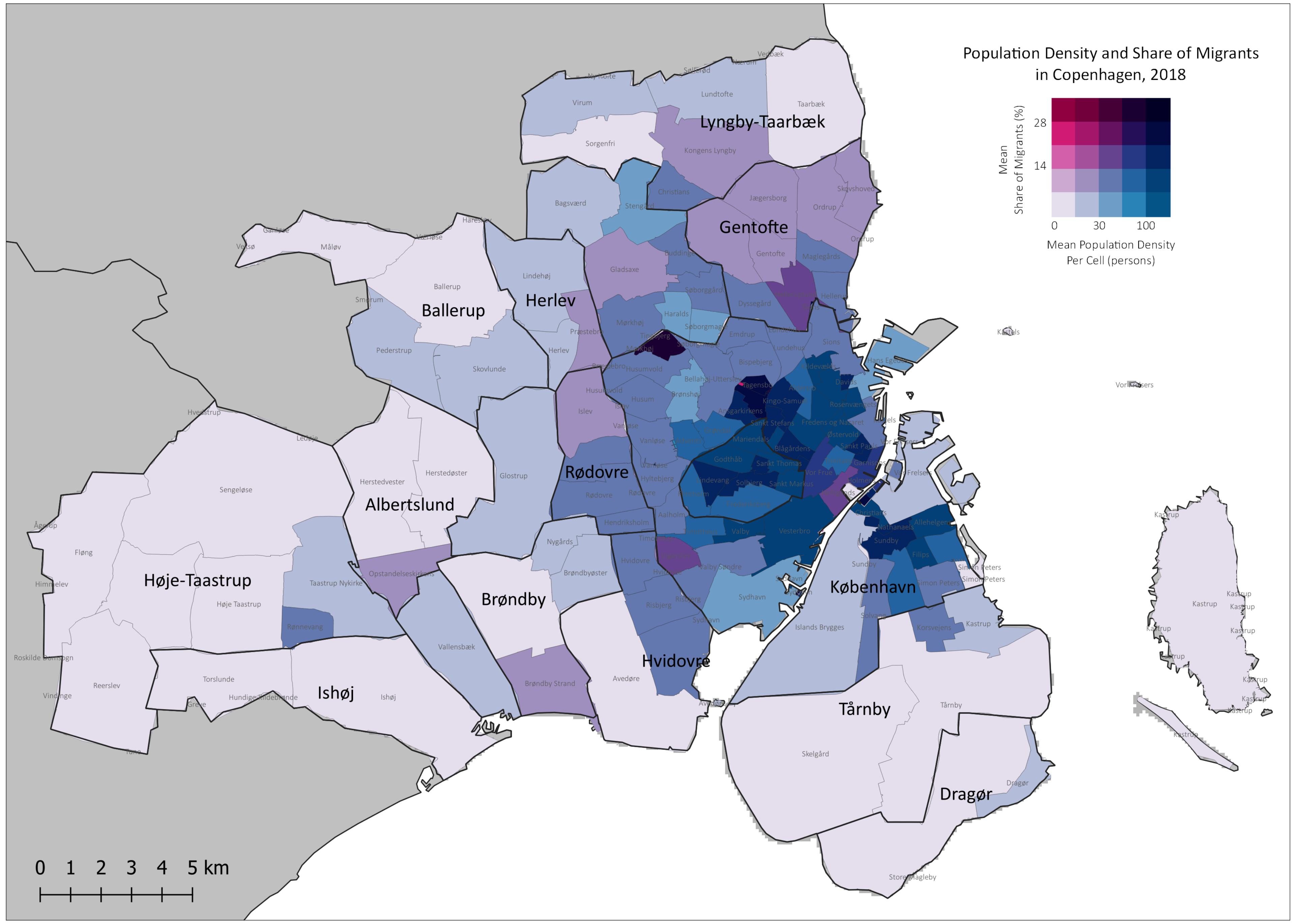






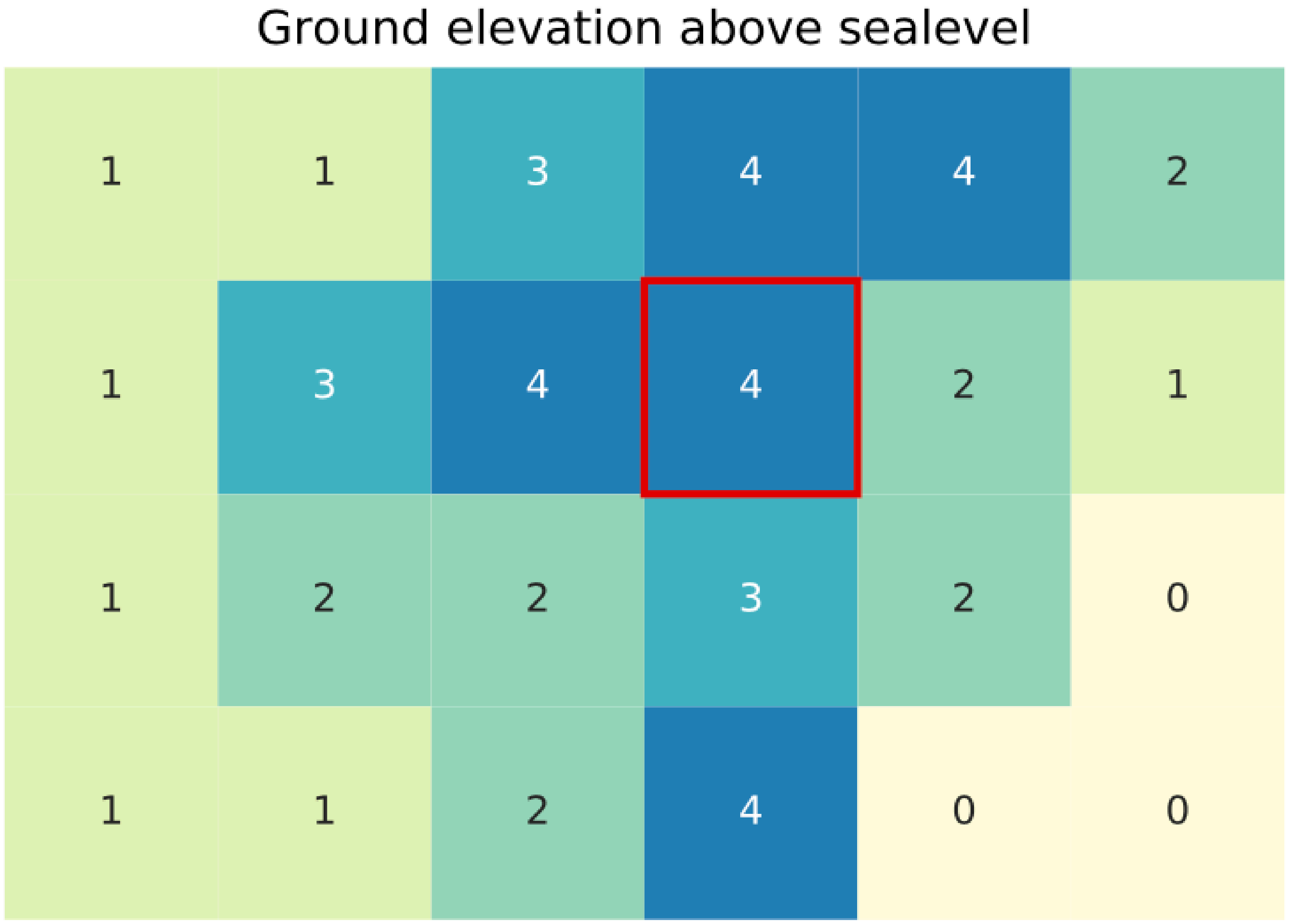
3. Zonal Operations





4. Global operations

- Work on **all cells** in the input raster
- Example: (Cost surface) that indicates the distance to the *closest source*

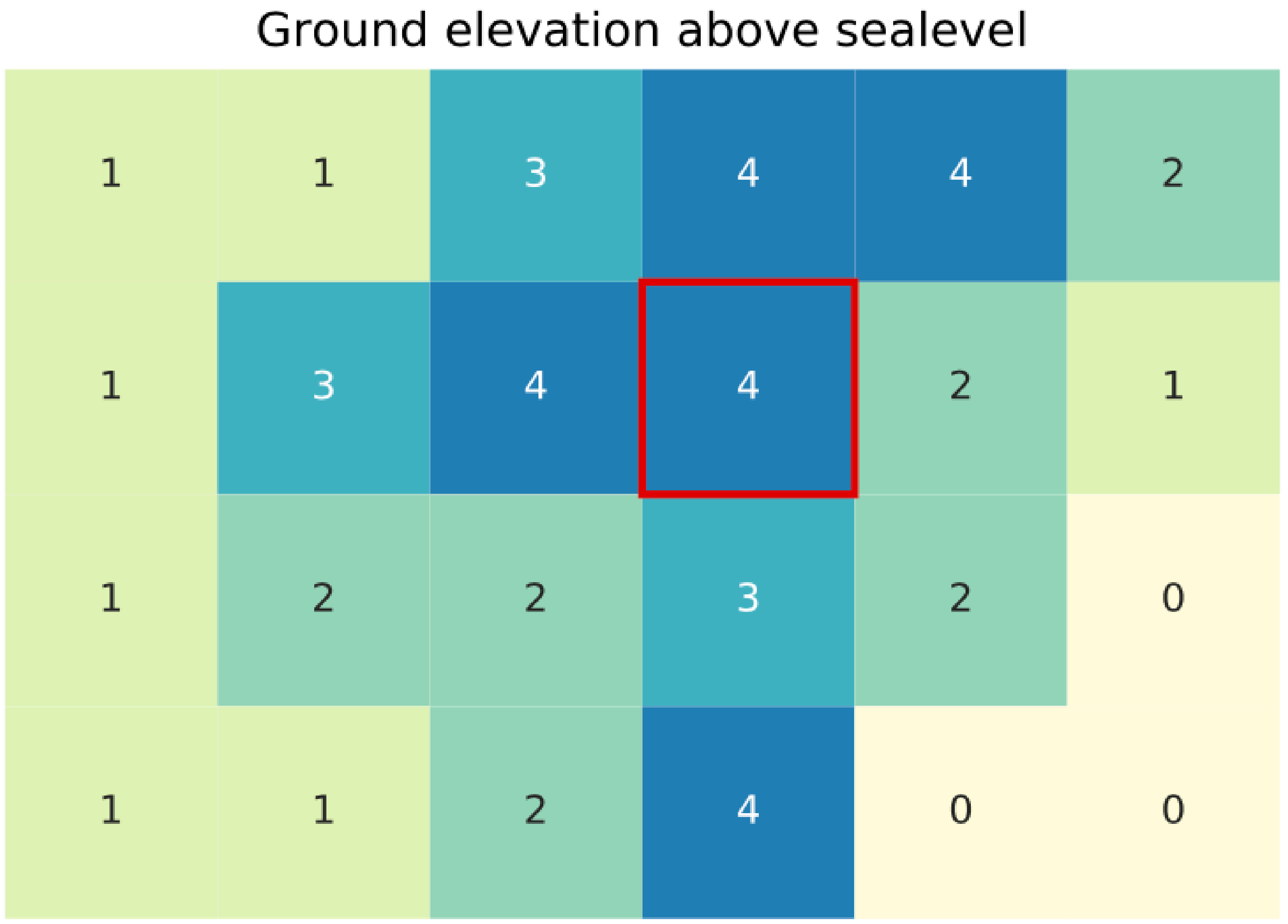


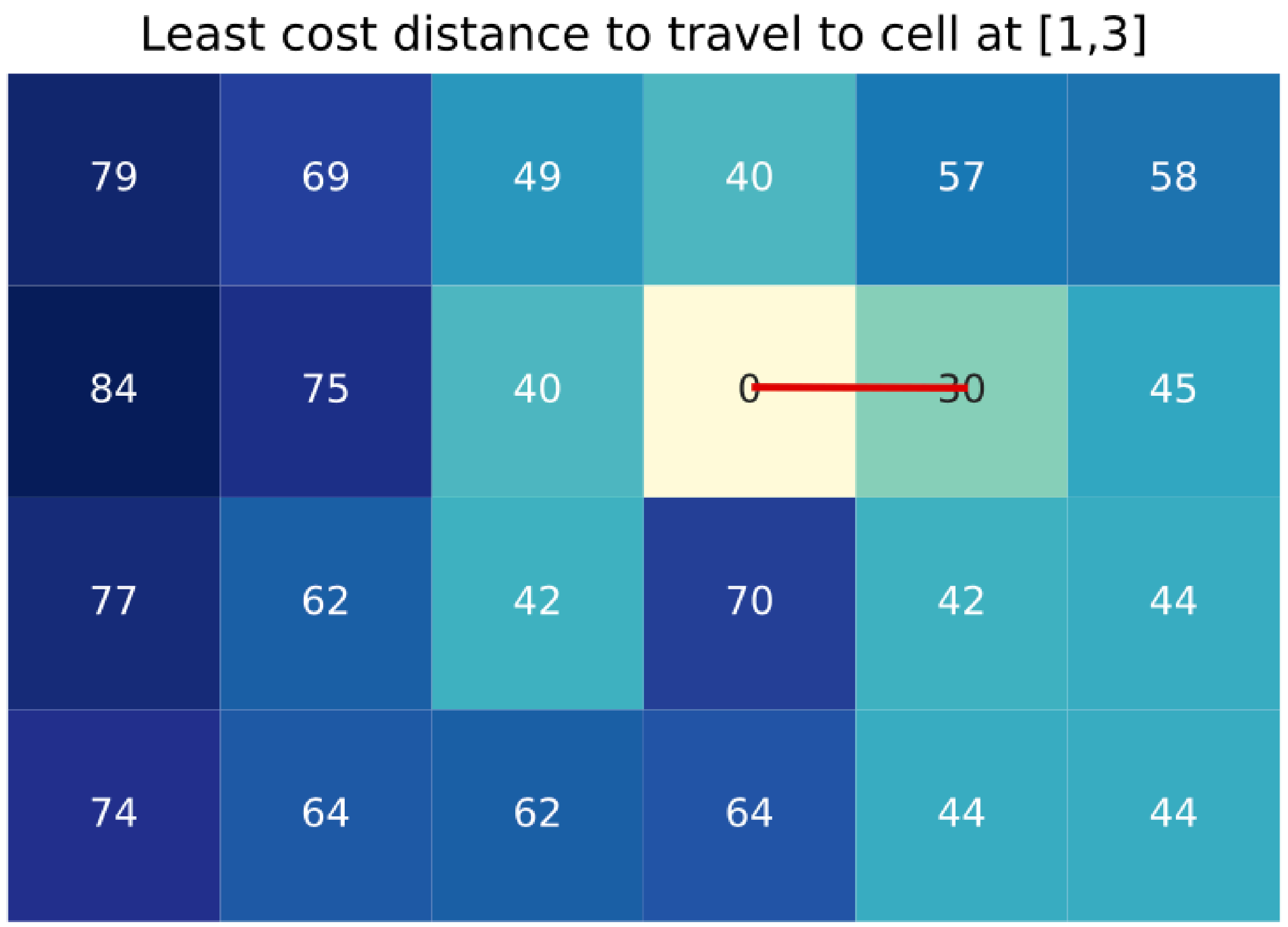
4. Global operations

- Work on **all cells** in the input raster
- Example: (Cost surface) that indicates the distance to the *closest source*

Cell size: 10m

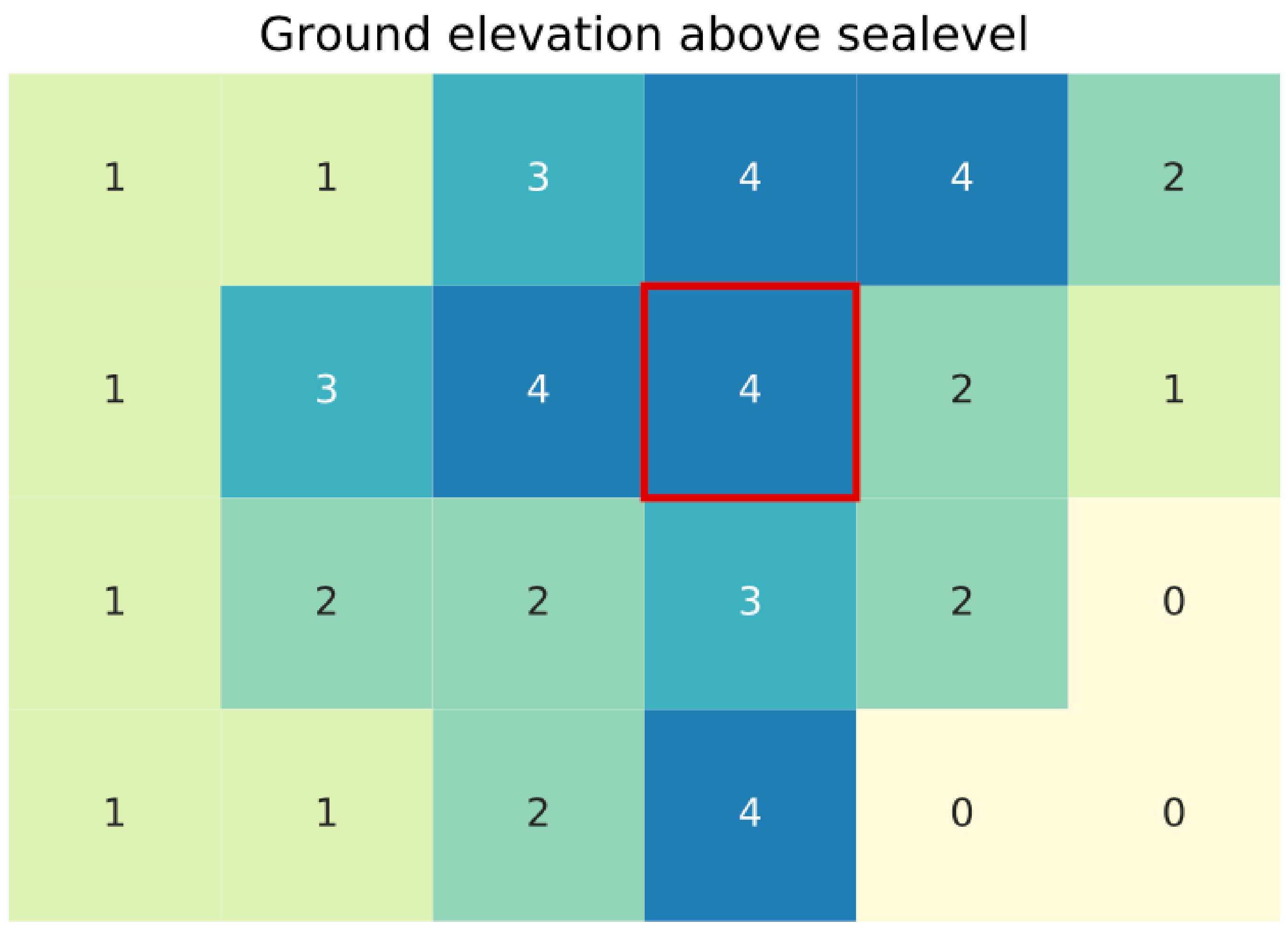
4 * 0.5 * 10 + 2 * 0.5 * 10 = 30





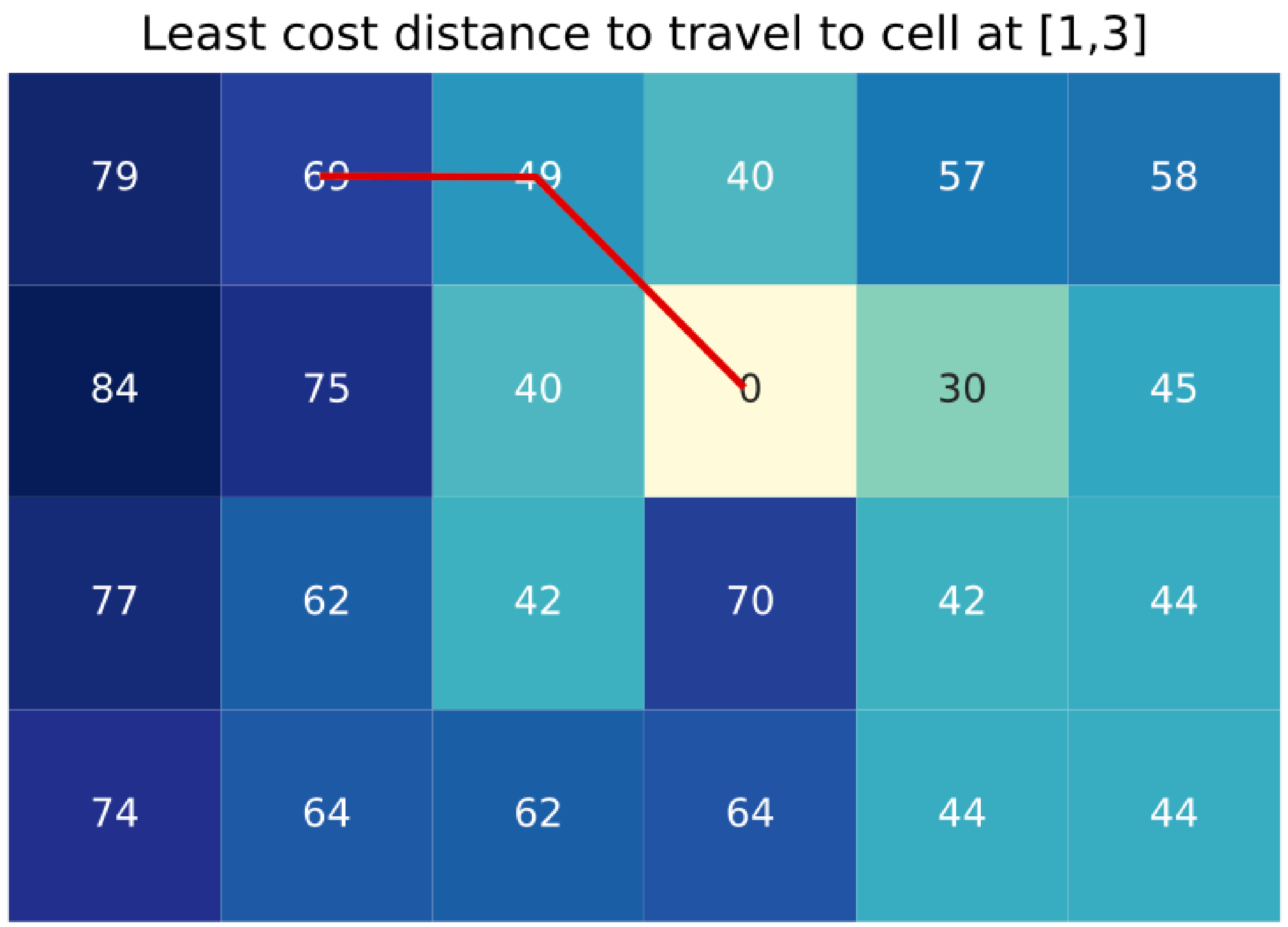
4. Global operations

- Work on **all cells** in the input raster
- Example: (Cost surface) that indicates the distance to the *closest source*



Cell size: 10m

4 * 0.5 * sqrt(200) +
3 * 0.5 * sqrt(200) +
3 * 0.5 * 10 +
1 * 0.5 * 10
= 69



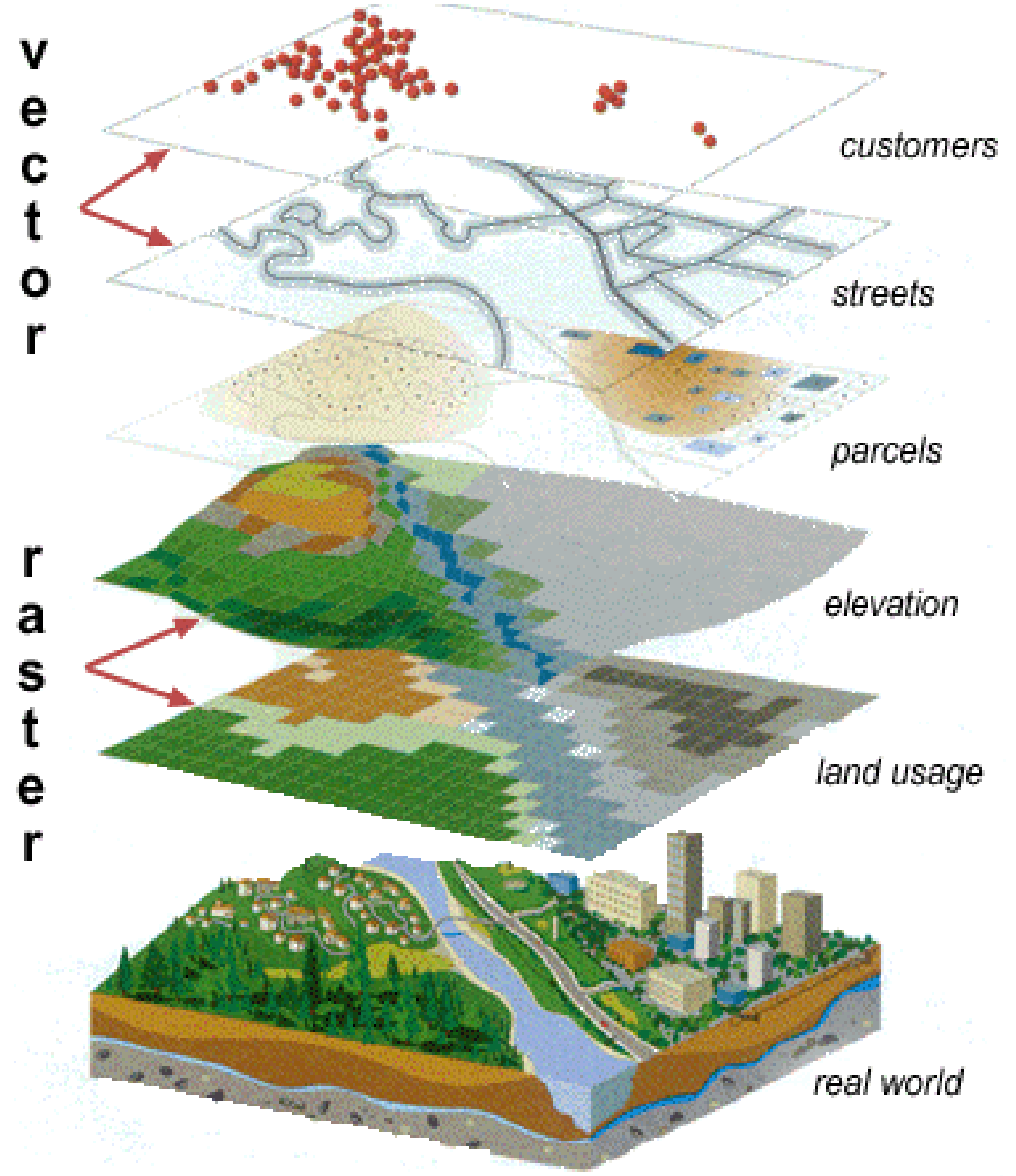
Discuss in groups

Extend your previous discussion into a mini mapping project where you process your raster data

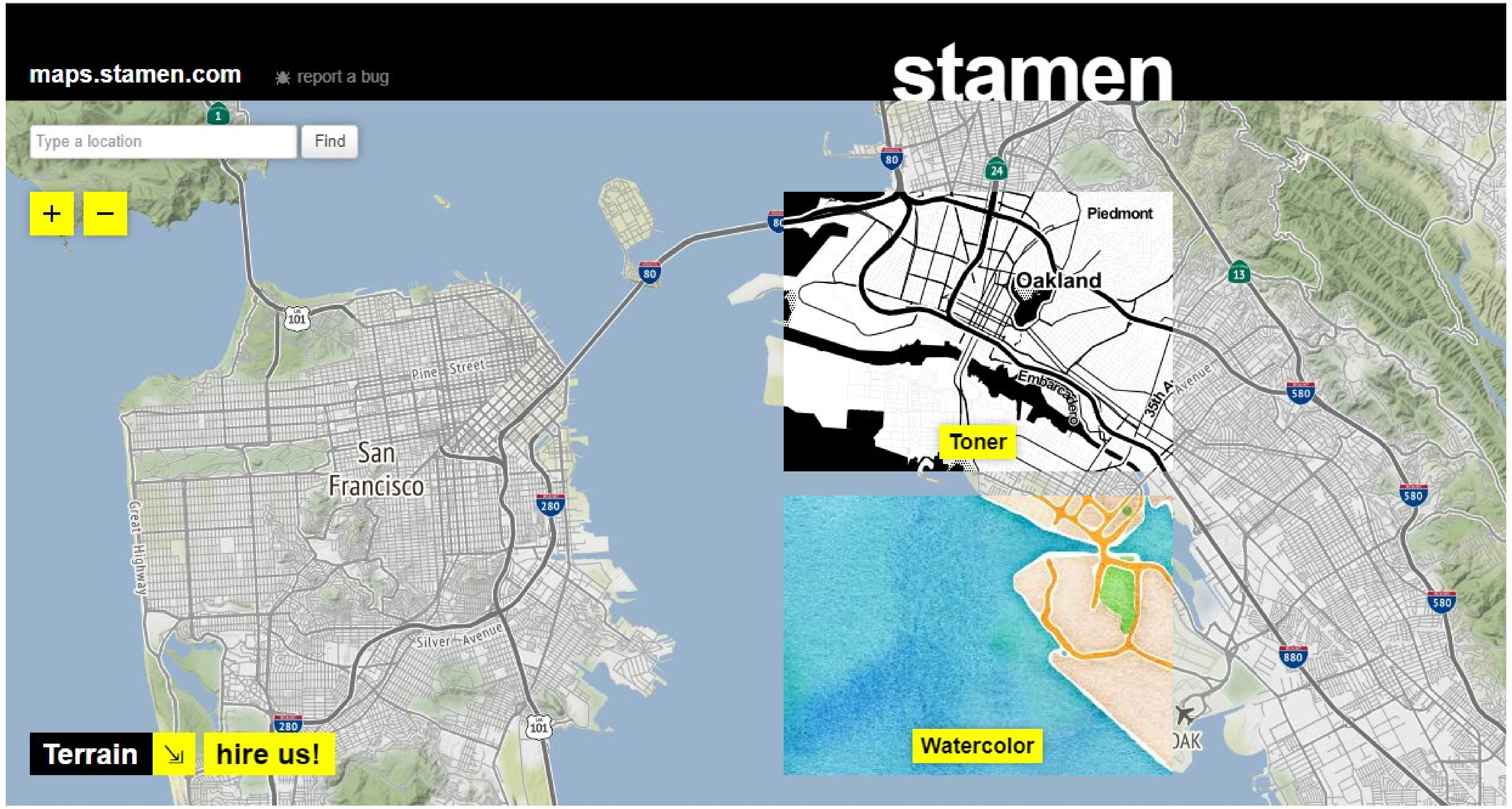
Define the topic you would like to map/communicate

What type of analysis would you do?
Which other data/ data types would you need?
What is the required spatial resolution?
What is the required temporal resolution?

What maps would you produce?



Next week: Easter Monday 😁



That’s all for today!!!

Next time together, GeoAI
Until then, questions at LearnIT or geor@itu.dk