Introduction to Geographic Information Science / Systems

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ESI-far Workshop
01/02/2024

40.000.000.000.000.000.000 GB

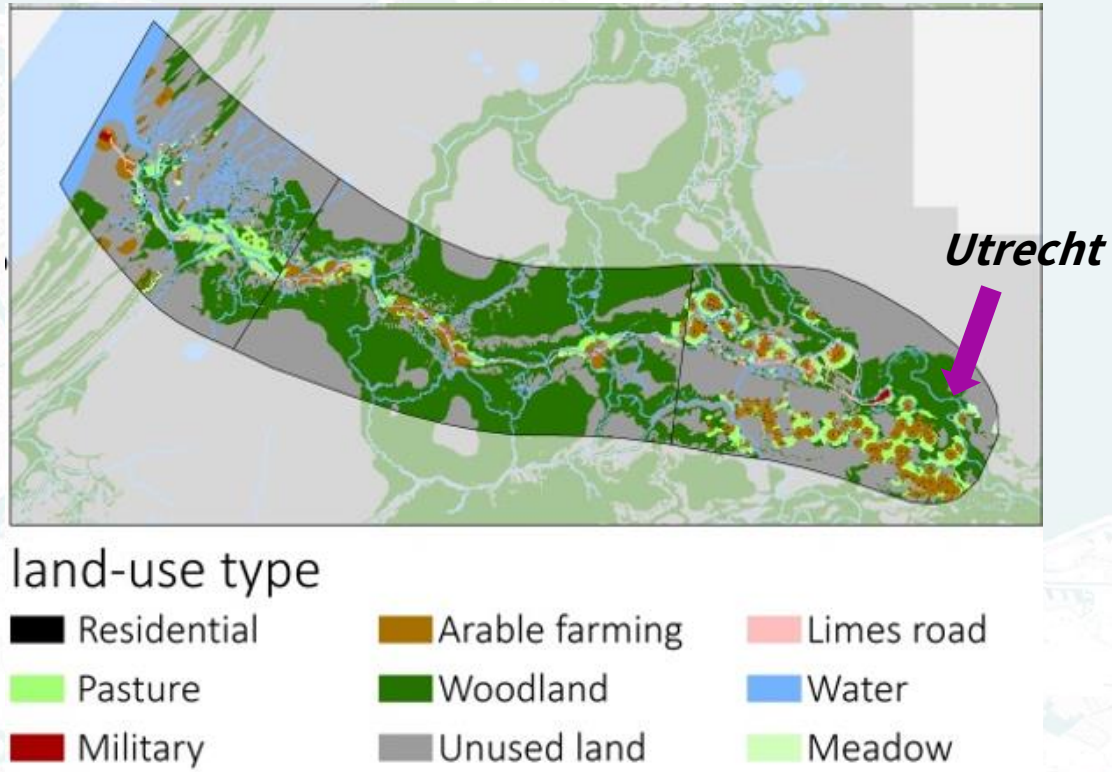
~ 80% is related to a location!

Guoa, et al. 2017: International Journal of Digital Earth, 10-1, 1-12

Why space matters for energy?

Simcity – 1989

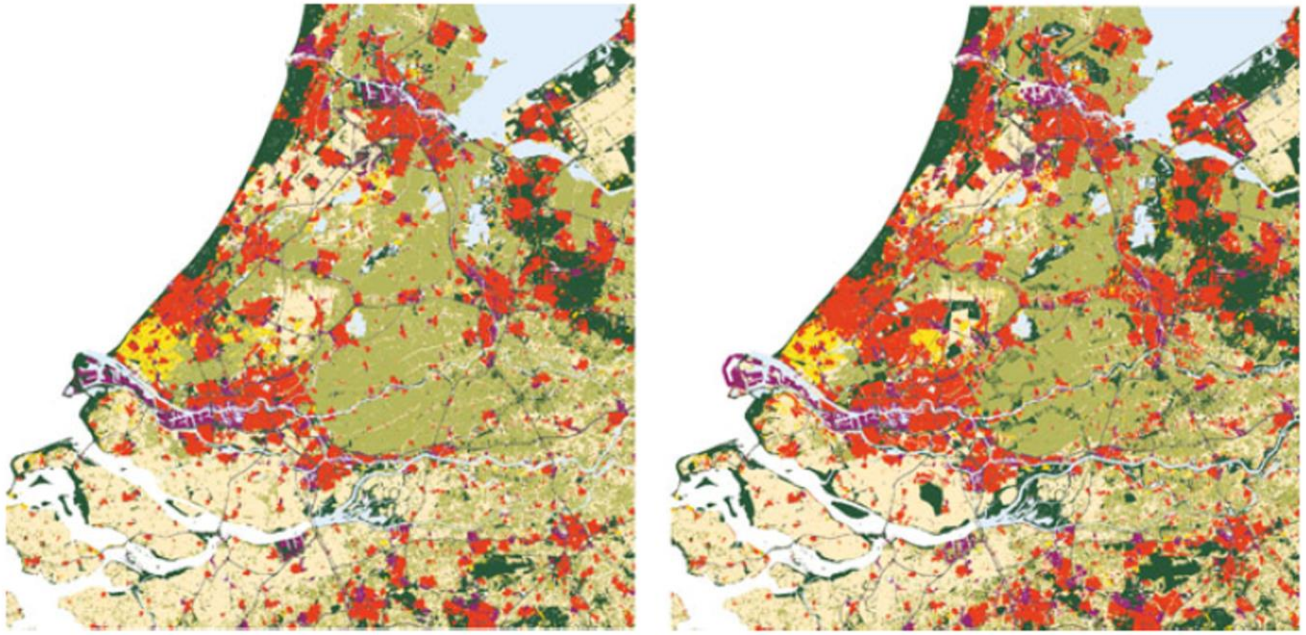
Simulating Roman Land Use - 70 CE



De Kleijn, M., Beijaard, F., Koomen, E., Van Lanen, R., (2018) Simulating past land use: a modelling framework integrating natural and cultural factors, *Journal of Archaeological Science Reports*. http://dx.doi.org/10.1016/j.jasrep.2018.04.006

Why space matters for energy?

Land use



2010

2040

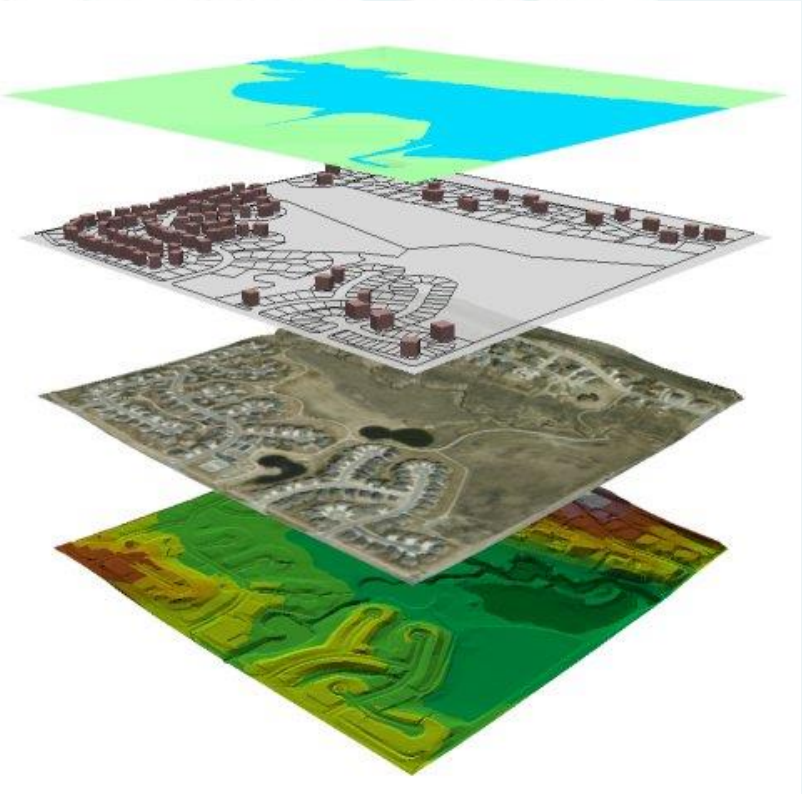
Residential
Recreation
Commercial
Nature
Arable land
Grassland
Greenhouses
Infrastructure
Water

Structure

1. What is GIS?
2. Spatial data models
   - Vector & raster
   - Spatial data Concepts: projections, scale, data capture
3. Spatial analysis
   - Queries, measurements & transformations
   - Raster operations
4. Energy and Geographic Information Science
5. Get started - > GIS data and software

1. What is GIS?

- **G**eographic, **G**eospatial
- **I**nformation
- **S**ystems, **S**cience



A computerised system to capture, store, update, manipulate, analyse and display geographically referenced information

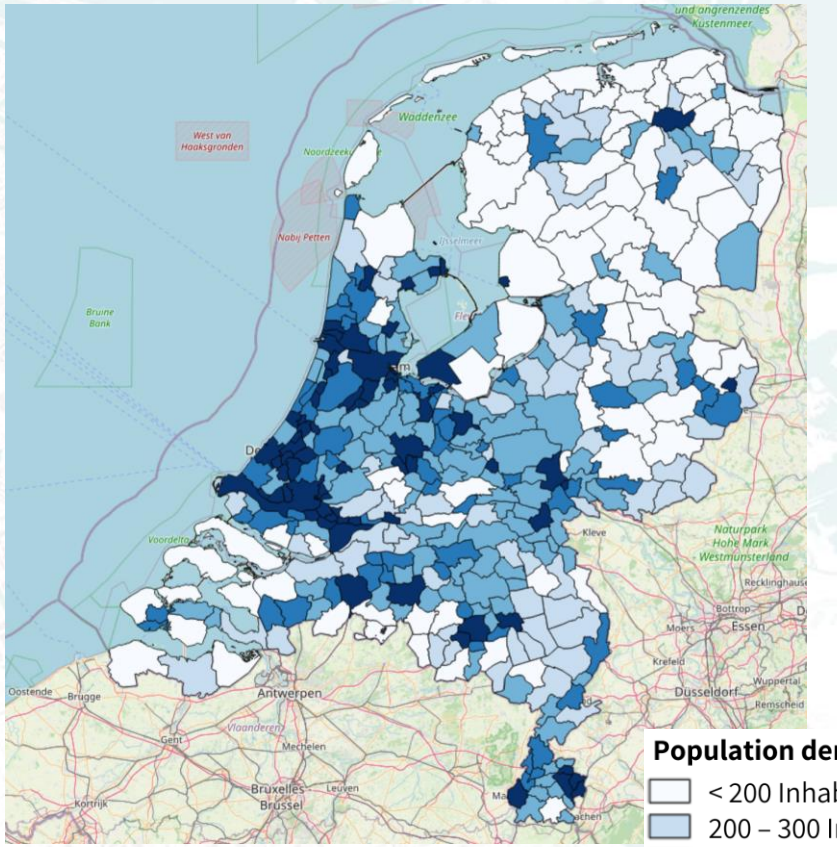
Research to solve (often) multidisciplinary and complex issues using geo-information systems, geo-informatics, remote sensing and data science.

1. What is a Geographic Information System?

GIS software let's you turn this

GEMNAAM	OPP_TOT	BEV_DICHTH	AANT_INW	PROVNR	PROVCODE	PROVNAAI
Appingedam	2462	511	12190	20	20	Groningen
Bedum	4496	238	10600	20	20	Groningen
Bellingwedde	11007	88	9510	20	20	Groningen
Ten Boer	4571	160	7250	20	20	Groningen
Delfzijl	22748	208	27650	20	20	Groningen
Groningen	8369	2327	181610	20	20	Groningen
Grootegast	8778	140	12150	20	20	Groningen
Haren	5070	412	18810	20	20	Groningen
Hoogezand-Sappemeer	7305	512	34390	20	20	Groningen
Leek	6427	303	19190	20	20	Groningen
Loppersum	11199	97	10780	20	20	Groningen
Marum	6488	156	10070	20	20	Groningen
Almere	24877	1388	180920	24	24	Flevoland
Stadskanaal	11996	290	34120	20	20	Groningen
Scheemda	11746	123	14120	20	20	Groningen
Slochteren	15884	100	15190	20	20	Groningen
Veendam	7871	369	28120	20	20	Groningen
Vlagtwedde	17051	99	16600	20	20	Groningen
Zeewolde	26897	79	19700	24	24	Flevoland
Skarsterlân	21689	145	27050	21	21	Friesland
Winschoten	2224	854	18480	20	20	Groningen
Winsum	10253	139	14000	20	20	Groningen
Boarnsterhim	16859	127	19310	21	21	Friesland
Zuidhorn	12837	147	18460	20	20	Groningen
Dongeradeel	26694	149	24860	21	21	Friesland
Achtkarspelen	10399	274	28140	21	21	Friesland
Ameland	26850	58	3460	21	21	Friesland
het Bildt	11651	119	10960	21	21	Friesland
Bolsward	942	1054	9600	21	21	Friesland
Dantumadeel	8749	227	19460	21	21	Friesland
Franekeradeel	10916	200	20570	21	21	Friesland
Harlingen	38767	618	15460	21	21	Friesland

Into this:



Population density per municipality

- < 200 Inhabitants per km2
- 200 – 300 Inhabitants per km2
- 300 – 700 Inhabitants per km2
- 700 – 1400 Inhabitants per km2
- >1400 Inhabitants per km2

www.edugis.nl

1. What is a Geographic Information System?

Information system to answer questions such as:

- Browse/simple display – where are buildings?
- Query and display – where are residential building of certain size?
- Map analysis – are the residential buildings located within flood-prone areas?
- Spatial analysis –what is the most suitable location for a powerplant?

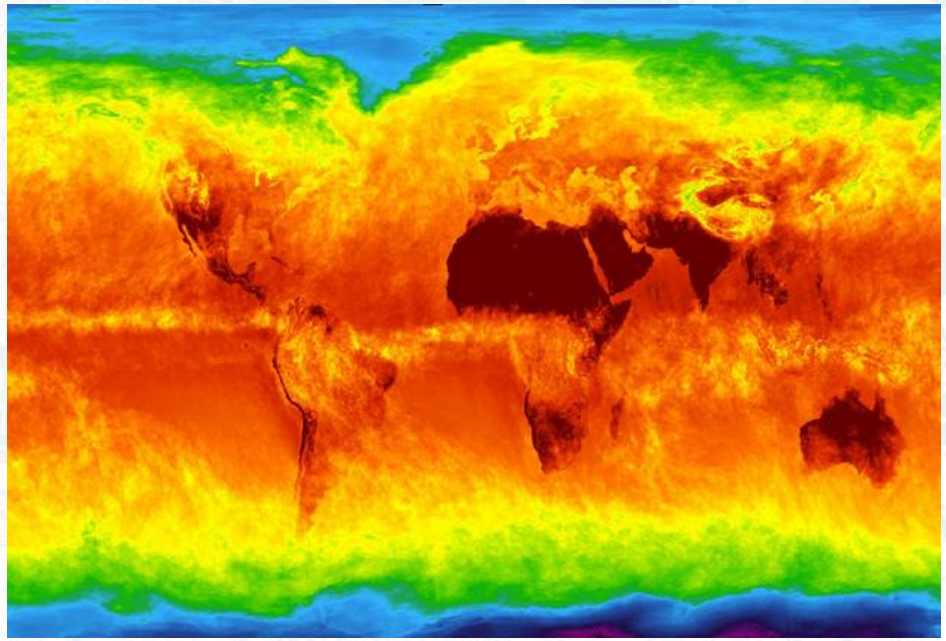
Structure

1. What is GIS?
2. Spatial data models
   - Vector & raster
   - Spatial data Concepts: projections, scale, data capture
3. Spatial analysis
   - Queries, measurements & transformations
   - Raster operations
4. Energy and Geographic Information Science
5. Get started - > GIS data and software

2. Spatial data models

<u>discrete</u> view and **<u>continuous</u>** view

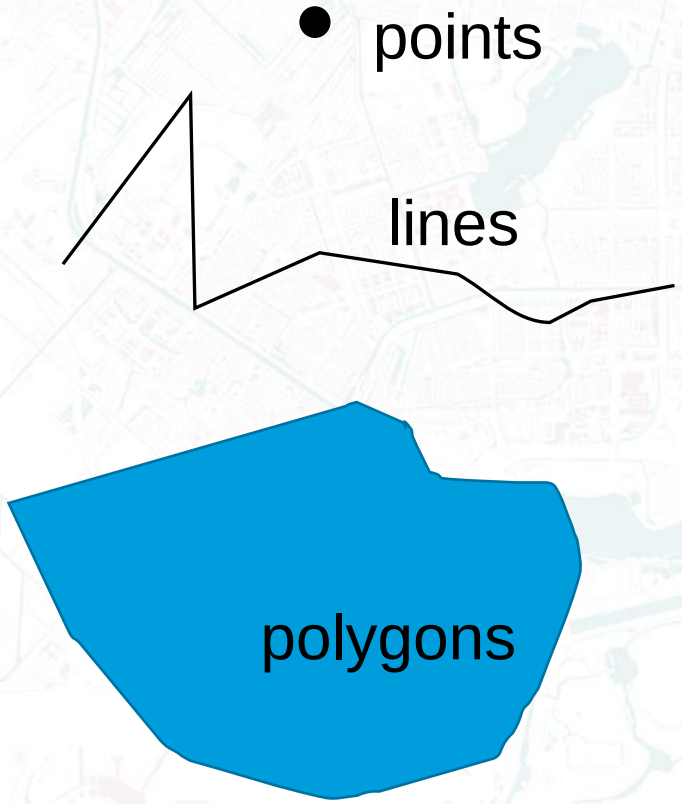
Discrete phenomena



Continuous phenomena

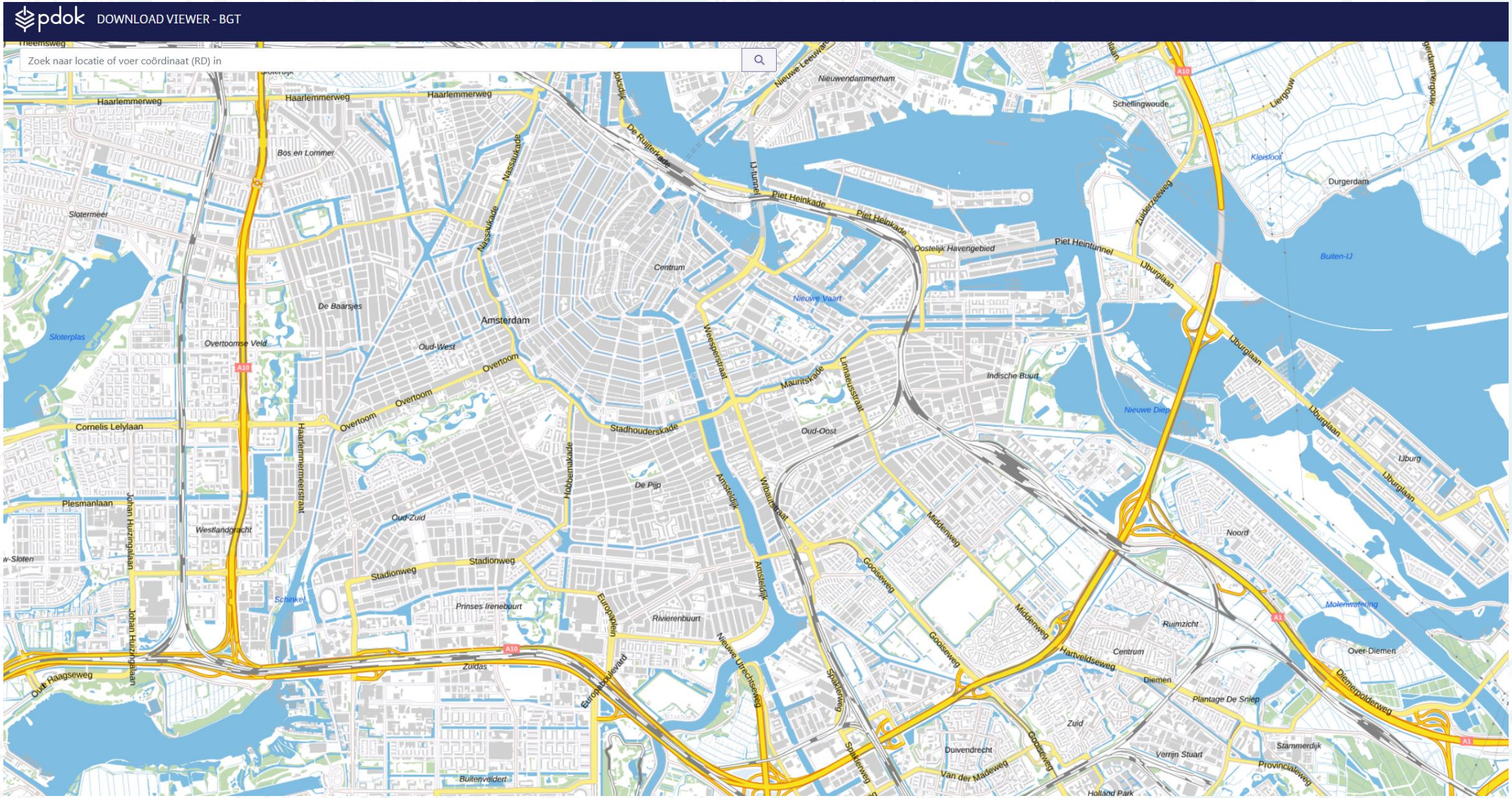
2. Spatial data models – Vector & Raster

Vectordata



- ‘discrete objects’: points, lines and polygons (areas)
- Represented as sequences of coordinates (**vertices**)
- To every object an attribute table can be connected.

2. Spatial data models – Vector & Raster



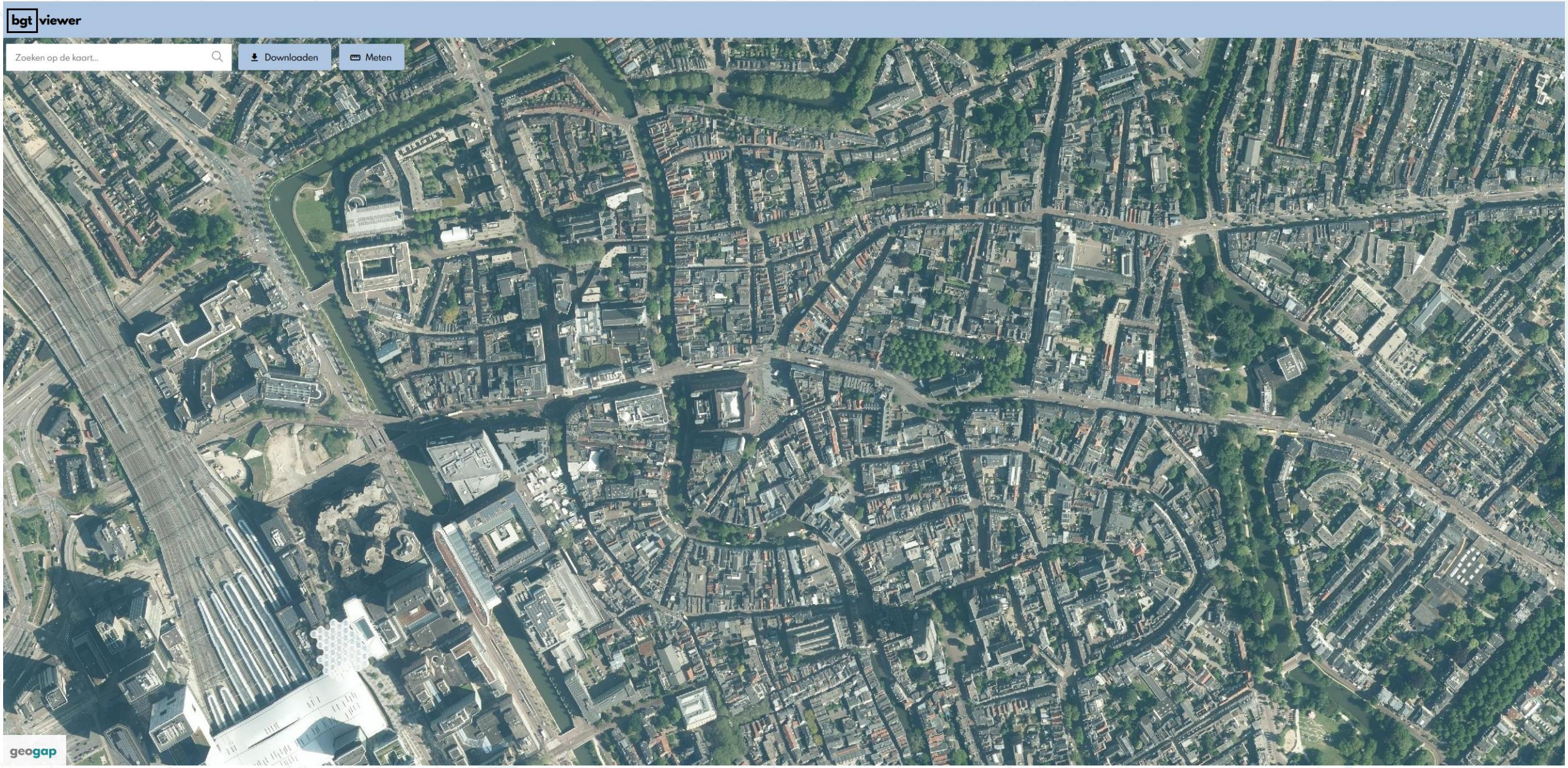
2. Spatial data models – Vector & Raster

Rasterdata

- rows and columns with numbers (matrix)
- Every cell in a raster has
  - a position
  - a value (or multiple)

1	1	1	1	1	1	1	3	3	3
1	1	1	1	1	1	1	3	3	3
1	1	1	1	1	1	3	3	3	3
1	1	1	2	2	2	2	3	3	3
1	1	1	2	2	2	2	3	3	3
1	1	1	2	2	2	2	3	3	3
1	1	1	1	2	2	2	3	3	3
1	1	1	1	1	1	3	3	3	3
1	1	1	1	1	1	1	3	3	3
1	1	1	1	1	1	1	1	3	3

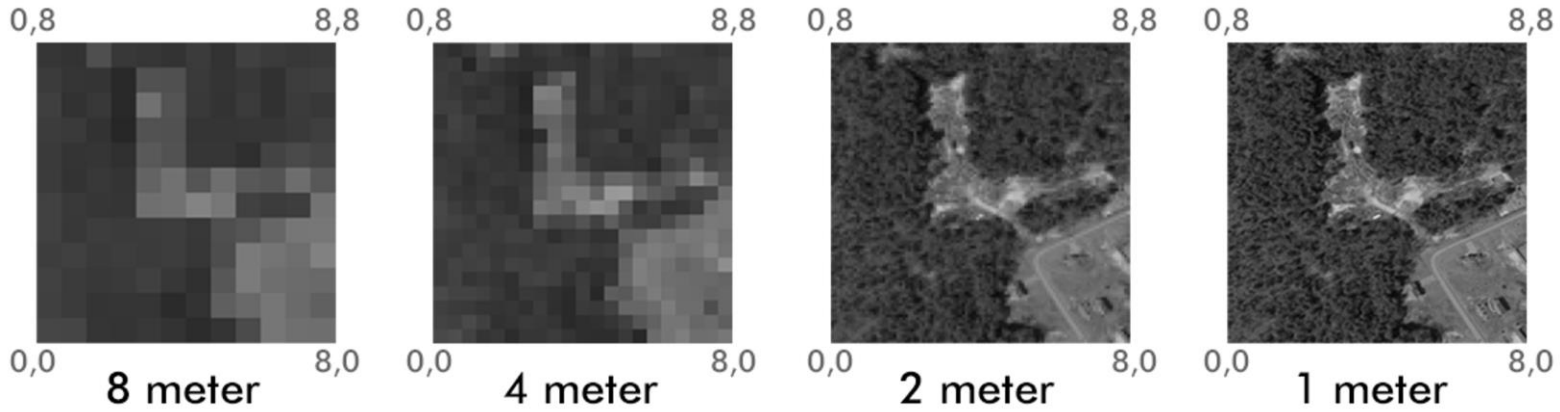
2. Spatial data models – Vector & Raster



2. Spatial data models – Vector & Raster

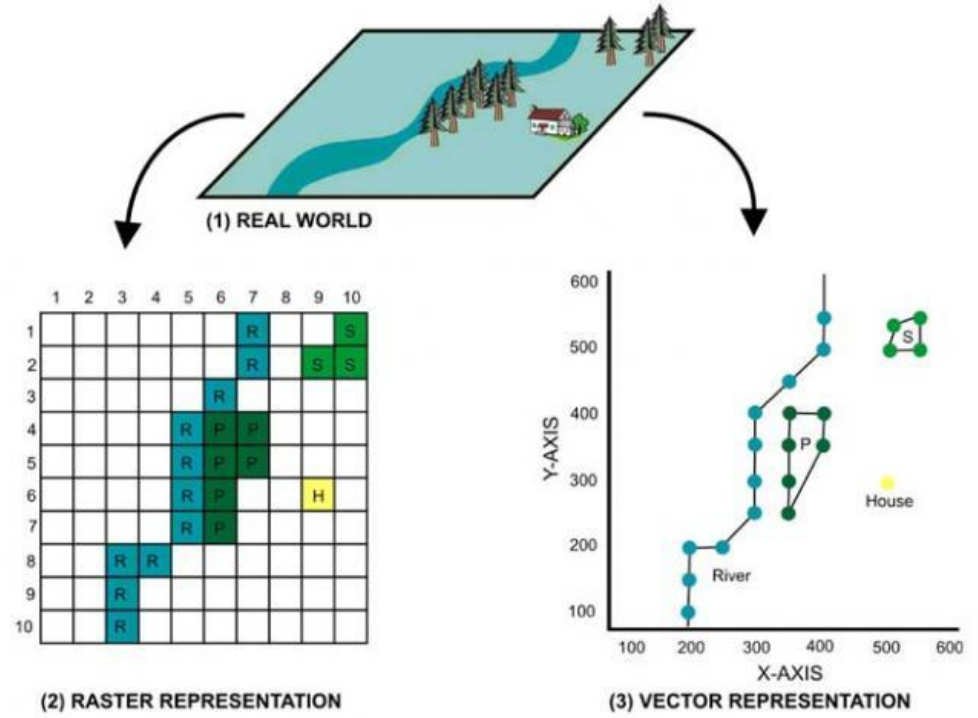
Rasterdata

Data resolution (detail) controlled by cell size



2. Spatial data models – Vector & Raster

Raster



Vector

You can represent many phenomena as raster and vector

(although representing continuous phenomena as vector is unusual)

2. Spatial data models – Data capture

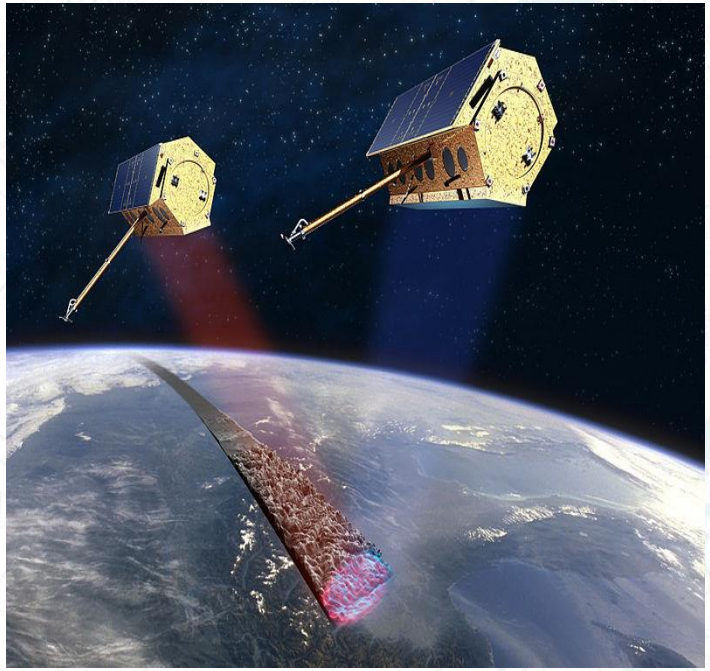
Primary data capture is where direct measurements made from real world objects can be put straight into a GIS. (no interpretations)

Secondary data capture is where we capture the data into the GIS from another existing data source. (interpretations)

2. Spatial data models – Data capture

Primary data captured data:

TerraSAR-X and TanDEM-X



IKONOSa

Bing satellite image

2. Spatial data models – Data capture

Primary data captured data:

Aerial photographs - Airplanes

(Stoker 2018)

Beeldmateriaal
Nederland

2. Spatial data models – Data capture

Primary data captured data:

DRONES

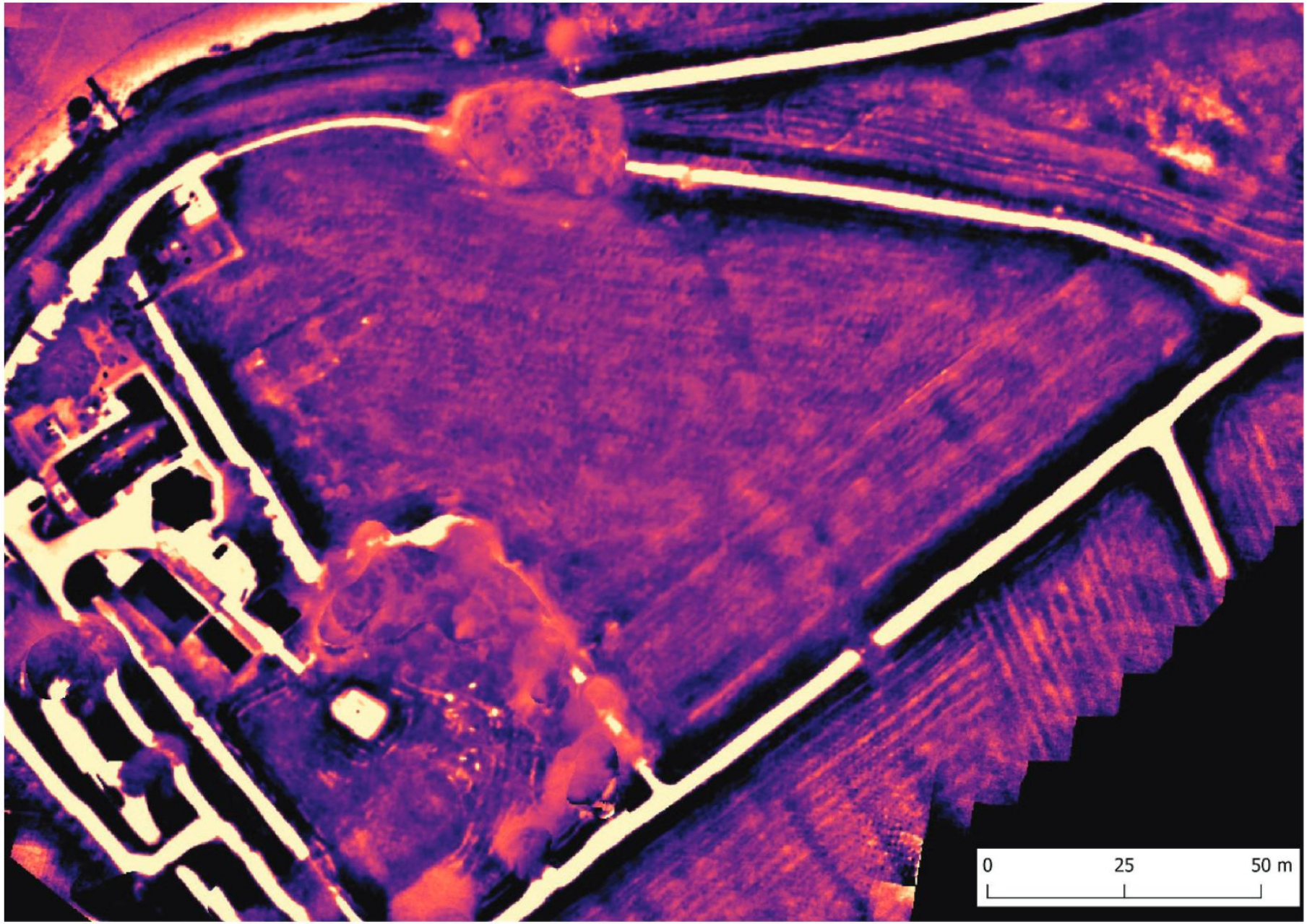
(Waagen 2022)

netherlands eScience center

June 2022, thermal mosaic (thermal sensor)

Drone data
Thermal scans

(Waagen 2022)

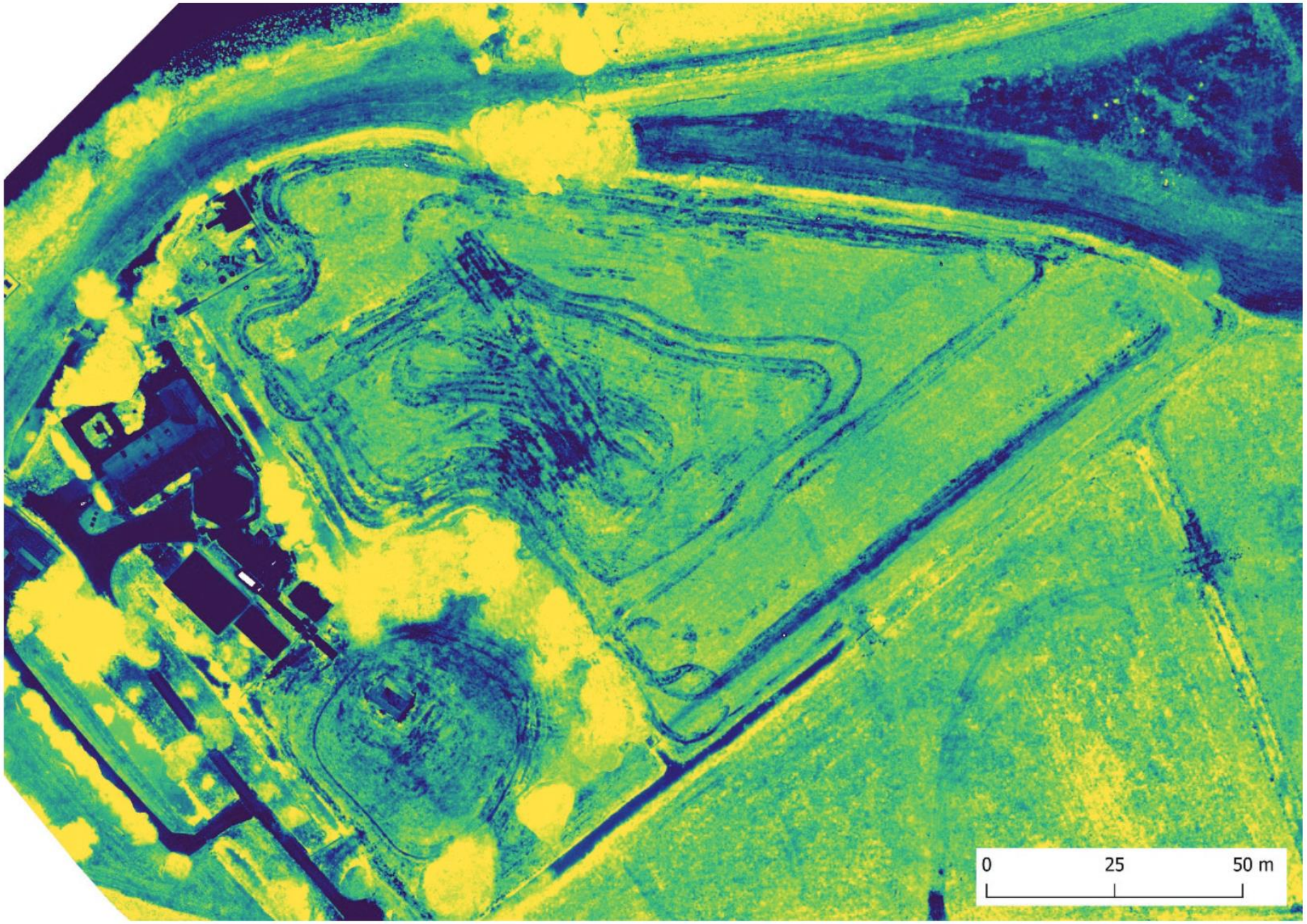


netherlands eScience center

September 2022, NDVI (multispectral sensor)

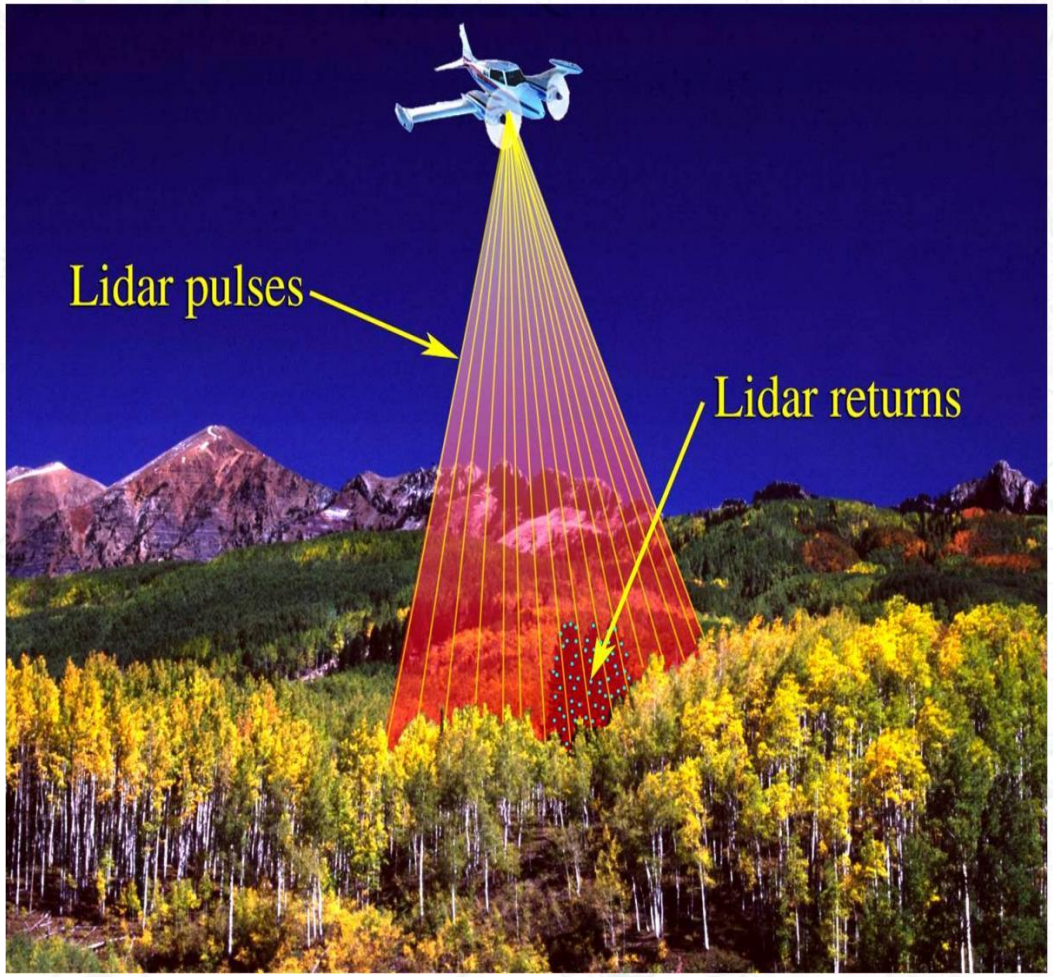
Drone data
NDVI
(vegetation index)

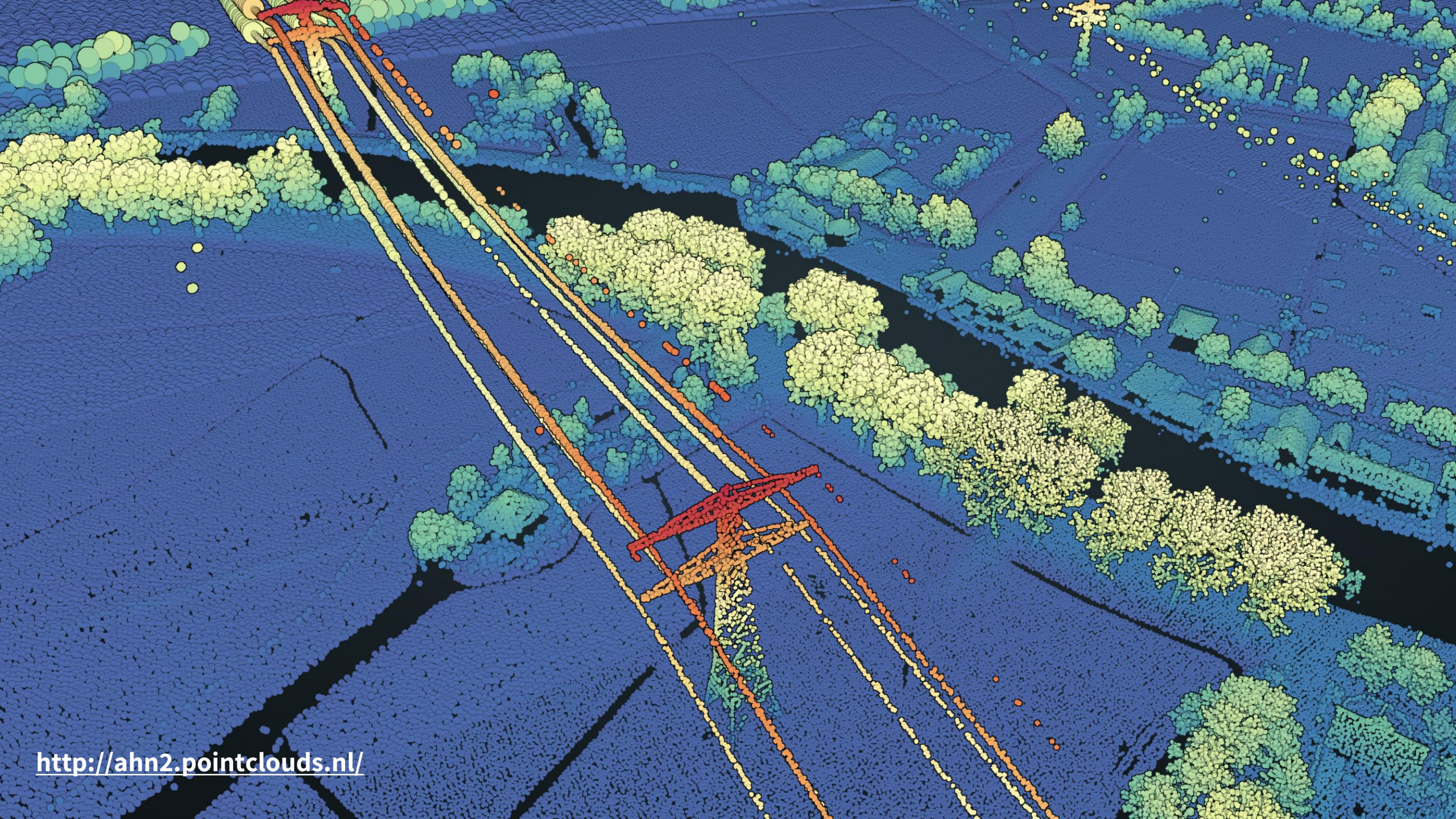
(Waagen 2022)



2. Spatial data models – Data capture

Primary data captured data:

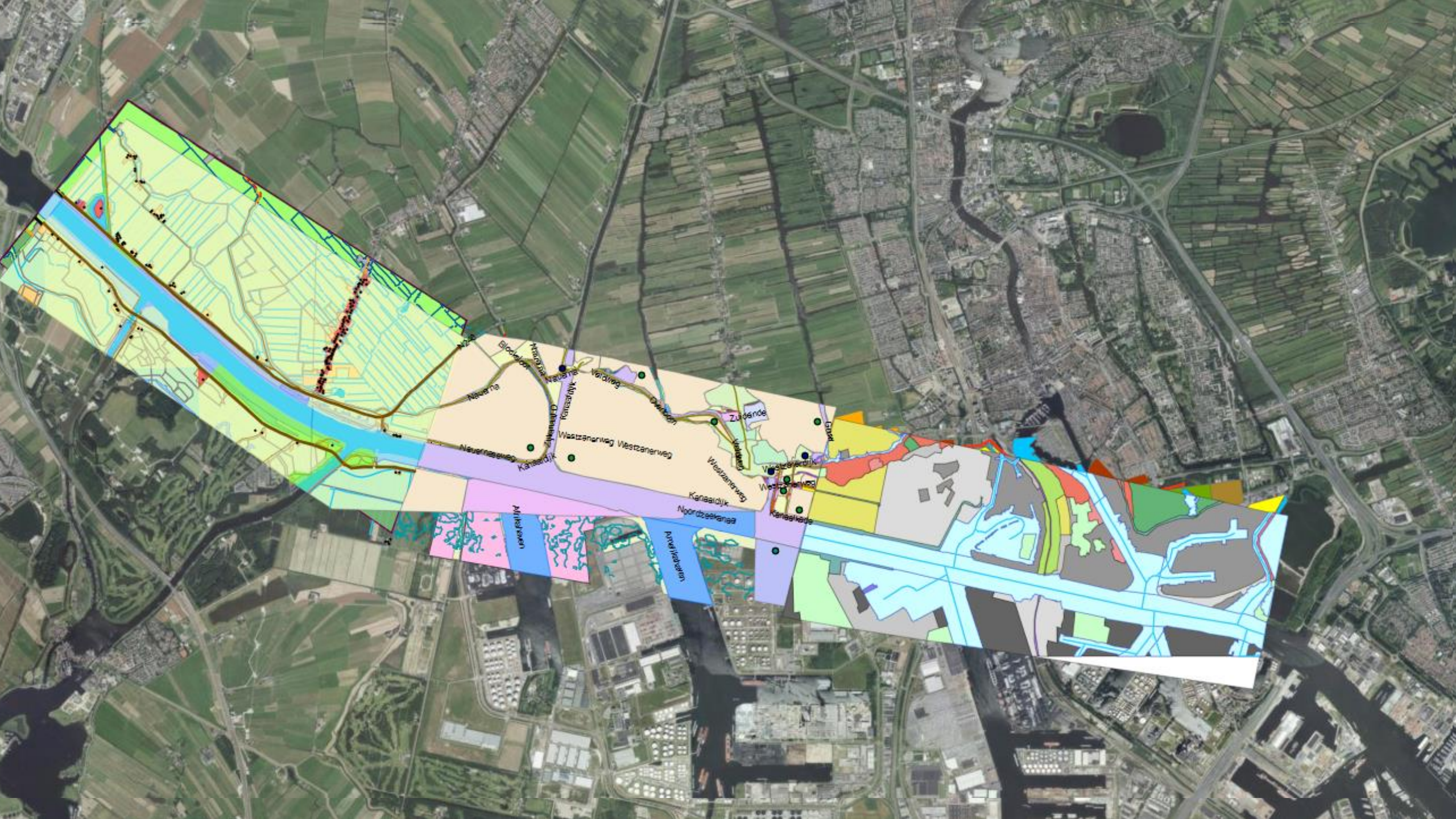



http://ahn2.pointclouds.nl/

2. Spatial data models – Data capture

Secondary data capture (interpretations)

What is a road ...?


Blockland
Nieuwe
Nieuwe
Molenweg
Kanaaldijk
Westzanerweg
Westzanerweg
Westzanerweg
Zuiderende
Kanaaldijk
Noordzeekanaal
Kanaaldijk
Alkmaarderkanaal
Noordhollandsch

2. Spatial data models – Data standards

INSPIRE KNOWLEDGE BASE

Infrastructure for spatial information in Europe

INSPIRE aims to create a European Union spatial data infrastructure for the purposes of EU environmental policies and applications. Member states establish and operate systems to share 34 spatial data themes with the goal of facilitate public (sector) access to spatial information across Europe and assist in policy-making across boundaries.

https://youtu.be/xew6qI-6wNk

2. Spatial data models – Data capture

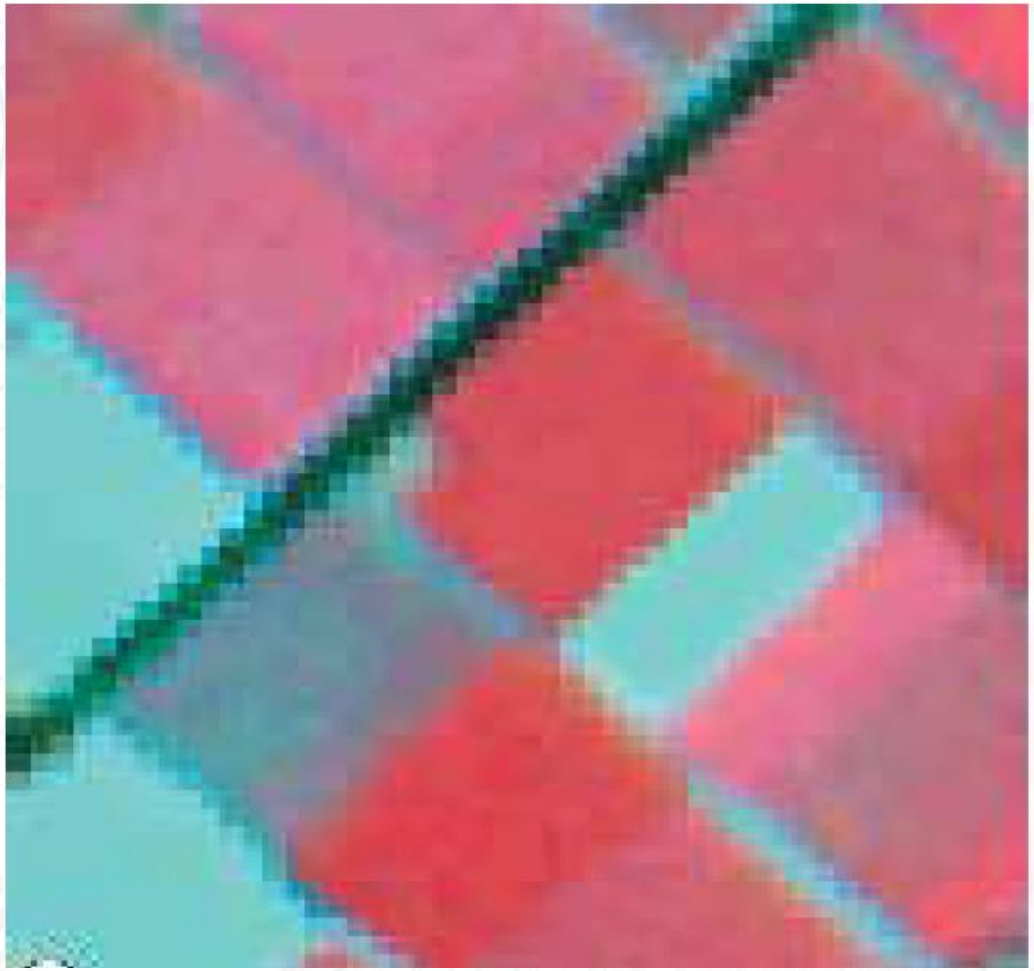
Secondary data capture

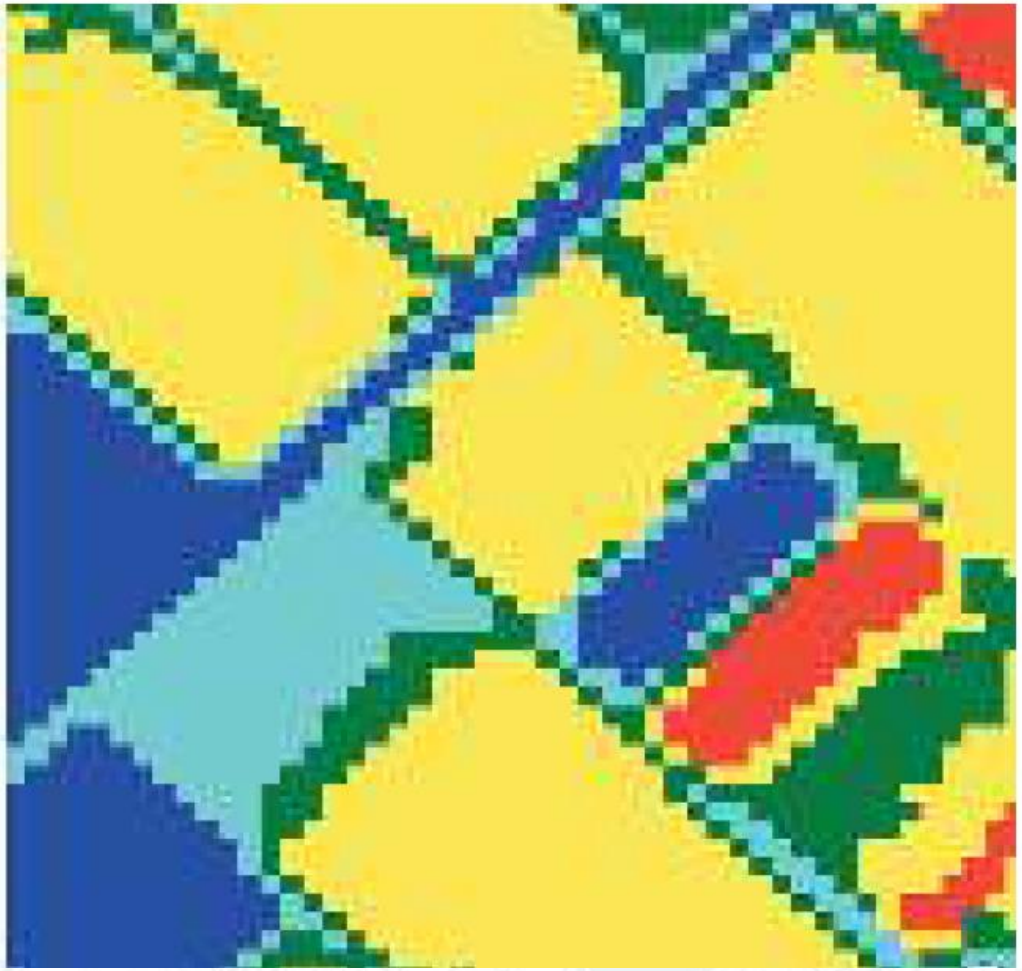
Digital Image Classification

- converting Remotely Sensed (satellite) images to thematic data
- human operator instructs the computer to perform an interpretation according to certain conditions, which are defined by the operator
- based on the different spectral characteristics of different materials

2. Spatial data models – Data capture

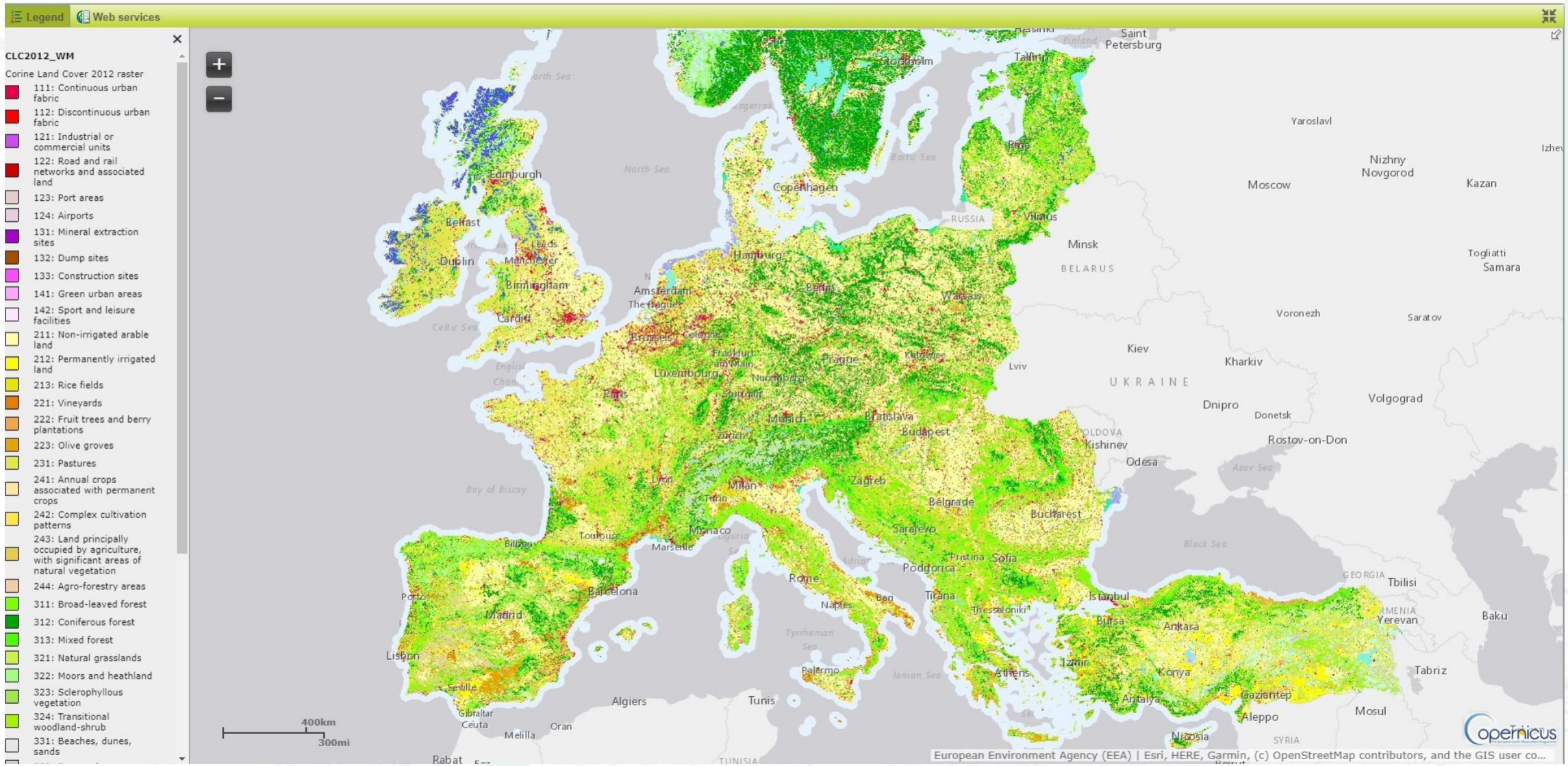
Digital Image Classification - example





2. Spatial data models – Data capture

Secondary data capture – Corine Landcover



2. Spatial data models – Data capture

Secondary data capture:

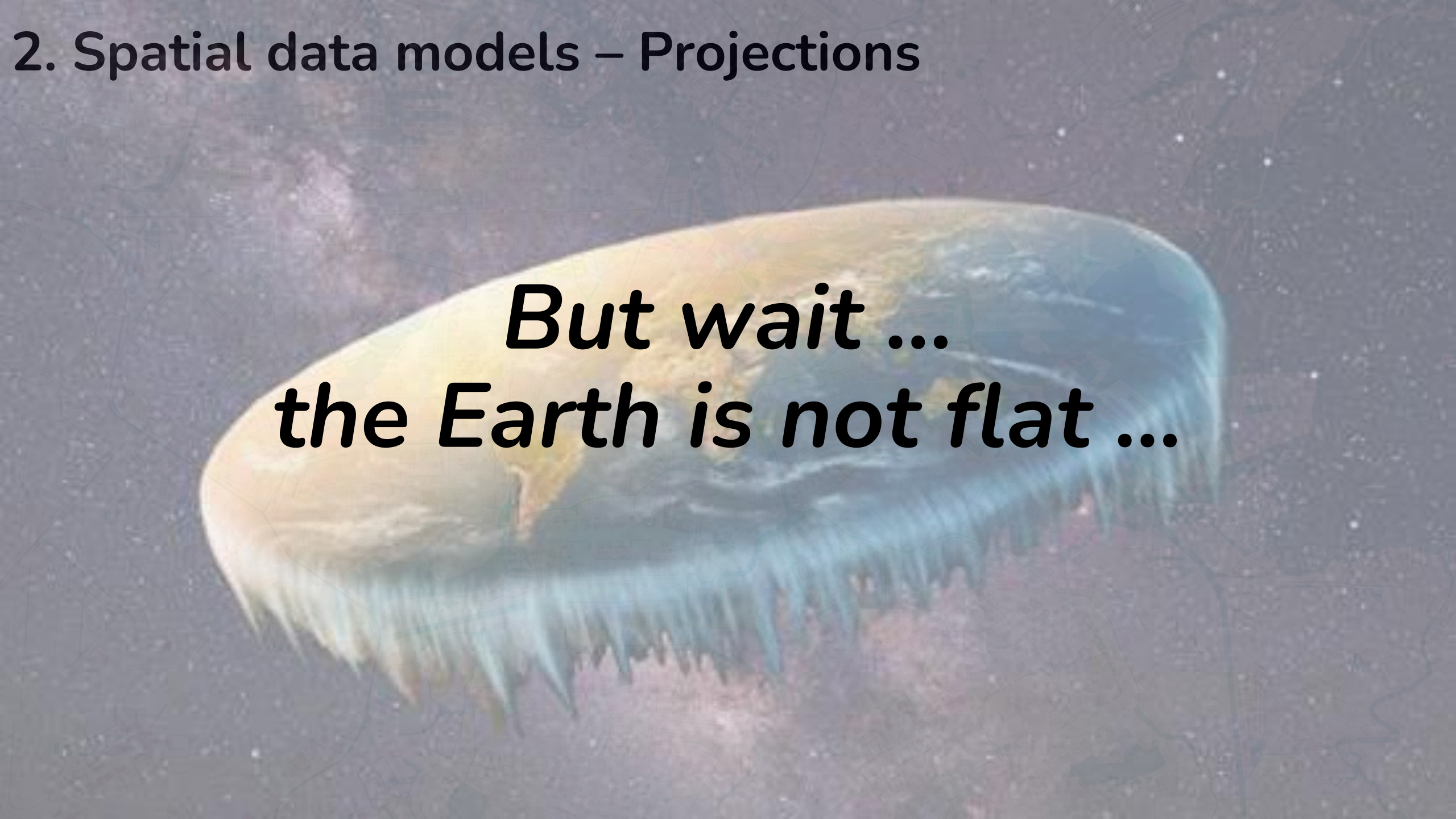
- The principal source of such data is normally government.
- Researcher needs to be aware that the information has been collected by someone else, for another purpose.
- Secondary data (particularly from government) tend to have been collected in ways that are much more robust than the means available to the individual research
- Secondary data may already have been manipulated for particular, possibly political, purposes; hence, secondary data may not be entirely trustworthy.
- Available secondary data are often strongly spatially referenced.
- There is a rapidly growing volume of altitudinal data available for secondary use.

(Paul White; 2010)

2. Spatial data models – Data capture

“Every (spatial) dataset is a simplification of reality!”

2. Spatial data models – Projections



But wait …
the Earth is not flat …

2. Spatial data models – Projections

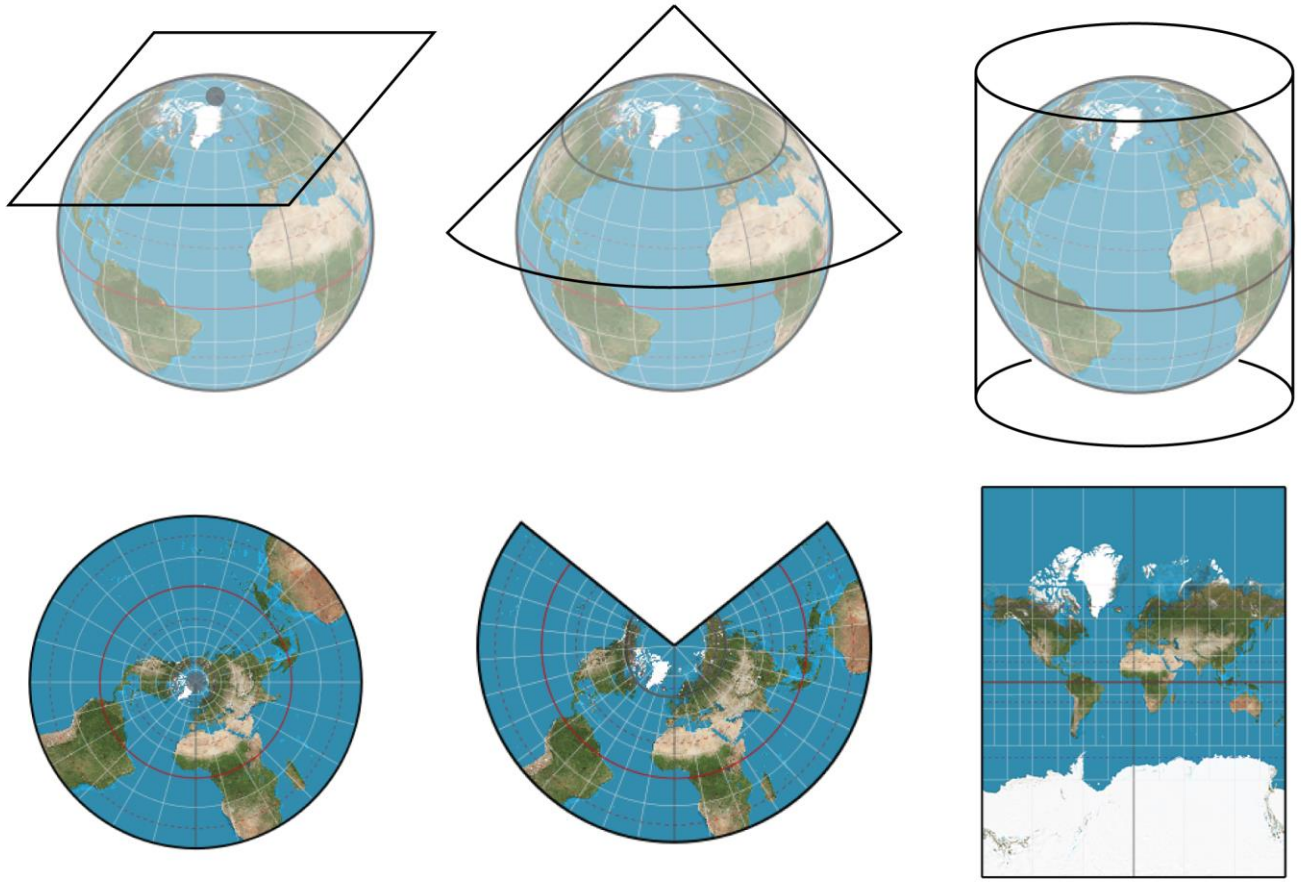
Coordinate Reference System (CRS)

Ellipsoid: is Earth an orange? Or a lemon?

Projection:
How can I peel this orange/lemon?

2. Spatial data models – Projections

Projected coordinate systems



https://gistbok.ucgis.org/bok-topics/2018-quarter-04/map-projections

2. Spatial data models – Projections

https://www.thetruesize.com/

Structure

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   - Vector operations
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3. Spatial analyses

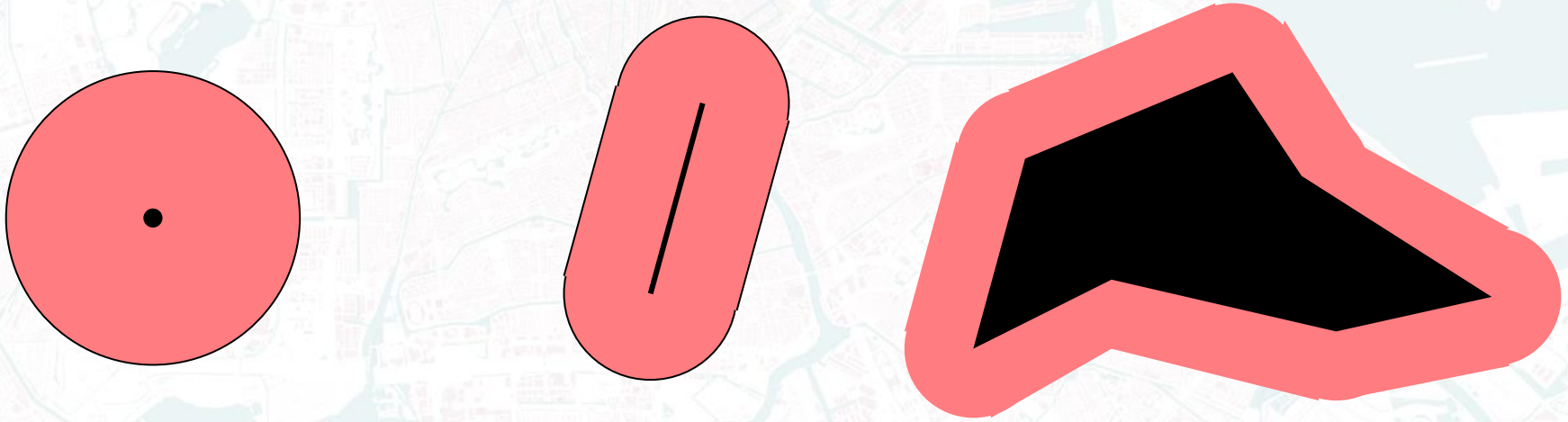
First law of geography:

"everything is related to everything else, but near things are more related than distant things."

Waldo Tobbler 1970

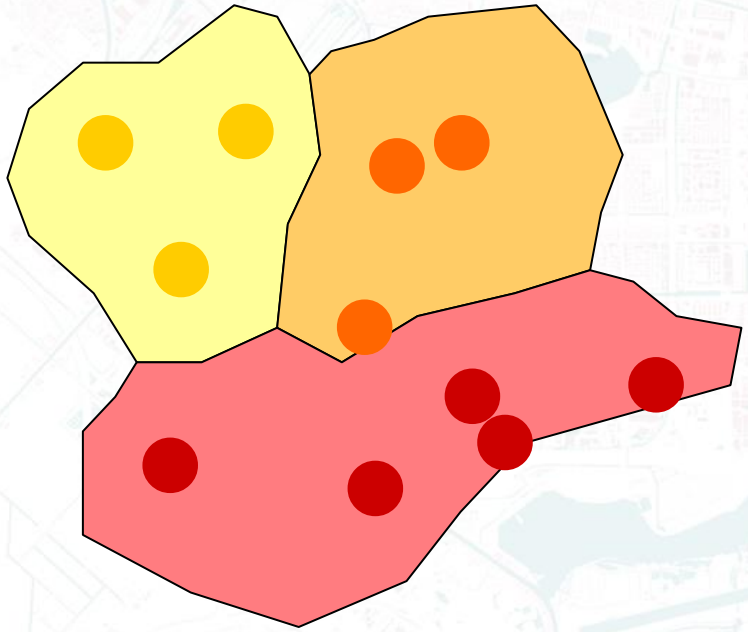
3. Spatial analyses – Vector analysis

buffer

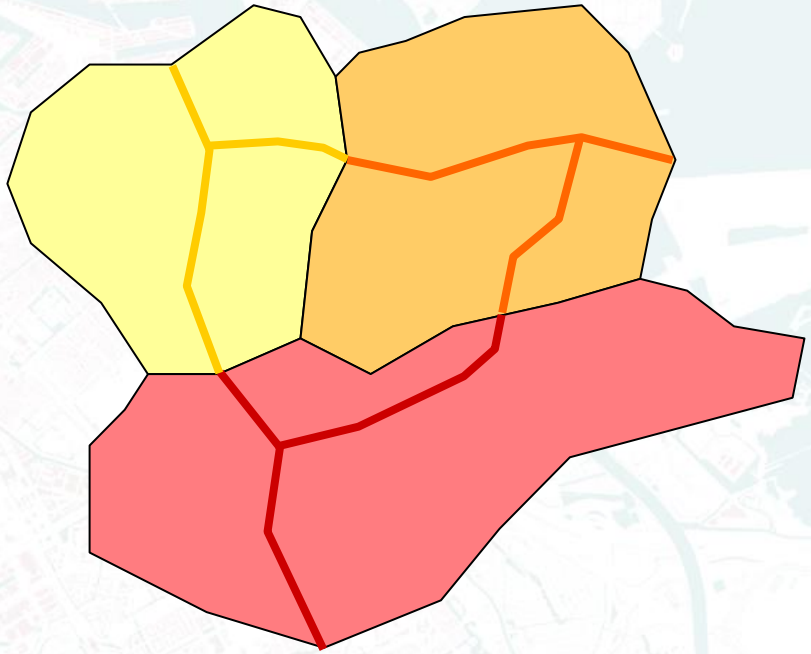


3. Spatial analyses – Vector analysis

point-in-polygon

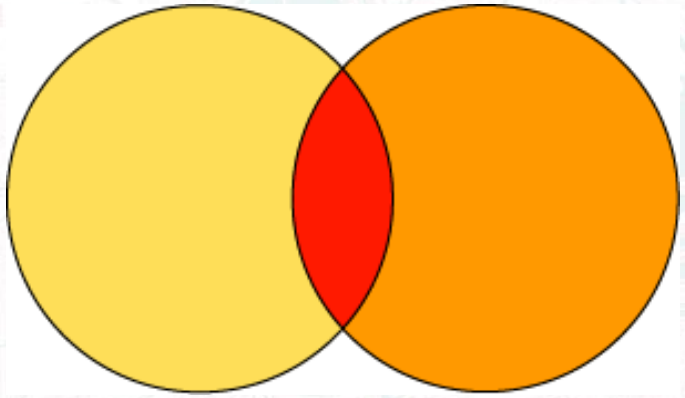


line-in-polygon

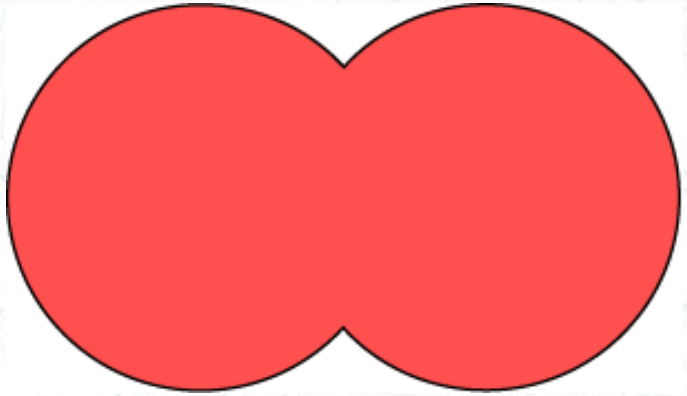


3. Spatial analyses – Vector analysis

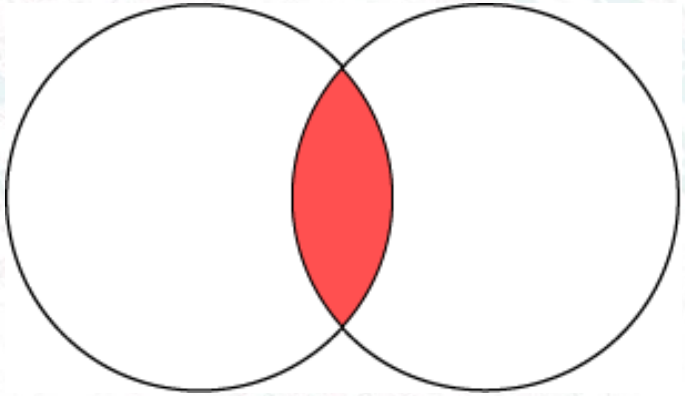
overlay



UNION



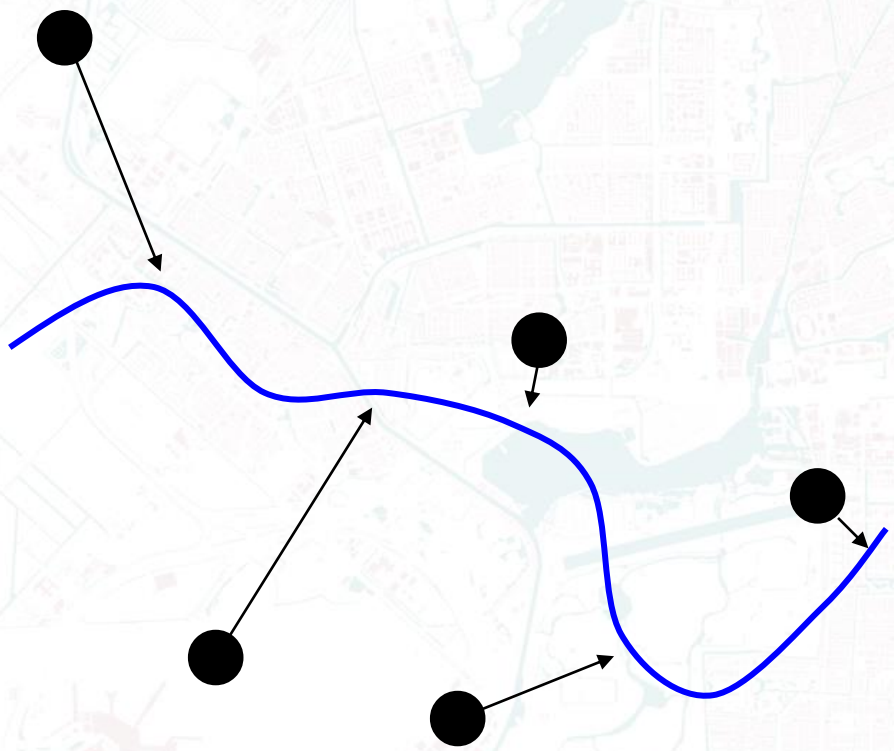
COMBINE/DISSOLVE



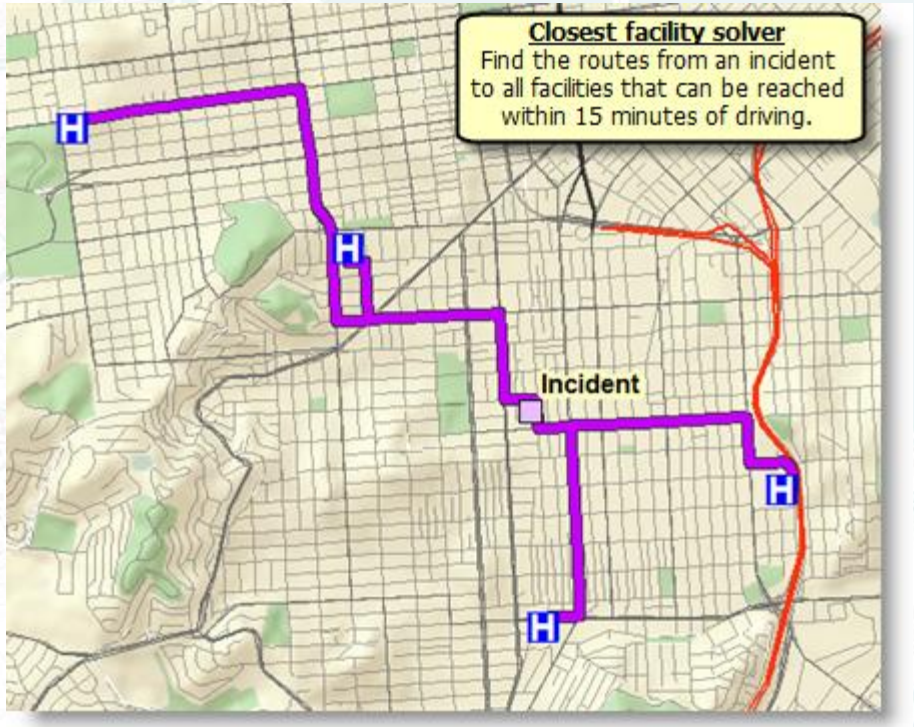
INTERSECT/CLIP

3. Spatial analyses – Vector analysis

Nearby



Network analysis



3. Spatial analyses – Raster analysis

- Map algebra / cartographic modelling
  - Sum (+), subtract (-), multiply (x), divide (:)
  - functies (sin, cos, tan, ln, log)
  - Reclassify
  - Logical operators screening (AND, OR, XOR) and ranking (MIN, MAX)

- Different Operations

Local Operations performed on a cell by cell basis

Focal Operations performed using a moving group of cells

Zonal Operations performed using zones (groups of cells having the same value)

Global Operations performed using the whole grid

3. Spatial analyses – Raster analysis

Local: Calculations

- Sum, Multiply, min max etc.

3	0	4
1	2	2
5	1	3

x 3 =

9	0	12
3	6	6
15	3	9

- Multiply with other raster

3	0	4
1	2	2
5	1	3

x

2	5	1
6	3	1
2	4	2

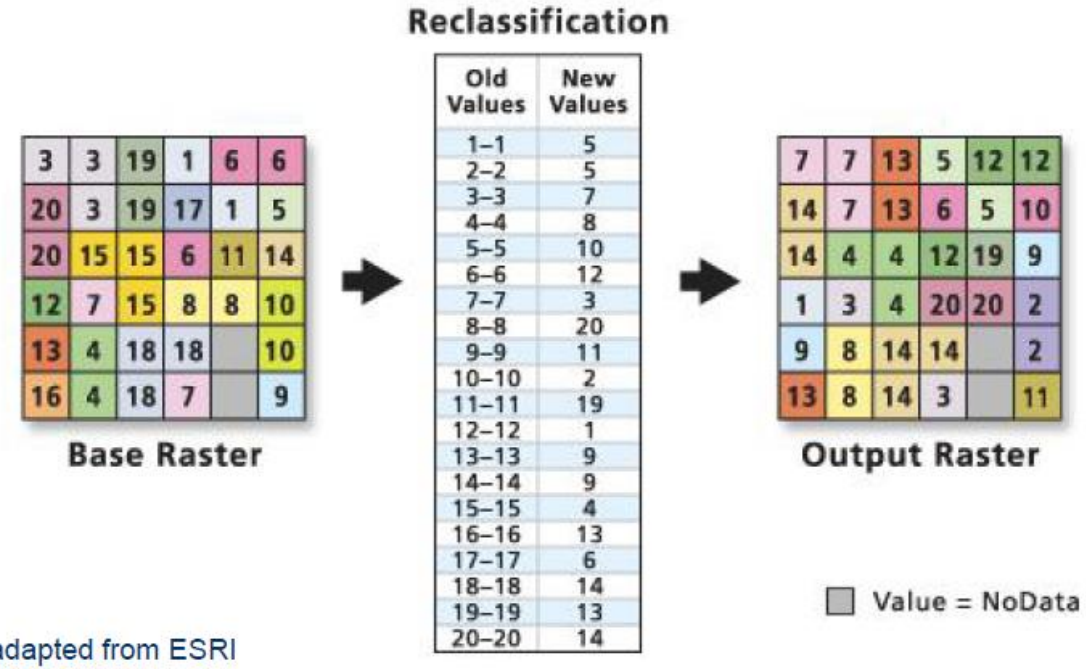
=

6	0	4
6	6	2
10	4	6

3. Spatial analyses – Raster analysis

Local: Reclassification

One-to-one change – input raster cell value is replaced with new value in the output raster (integer rasters only)



Old Values	New Values
1–1	5
2–2	5
3–3	7
4–4	8
5–5	10
6–6	12
7–7	3
8–8	20
9–9	11
10–10	2
11–11	19
12–12	1
13–13	9
14–14	9
15–15	4
16–16	13
17–17	6
18–18	14
19–19	13
20–20	14

Diagram adapted from ESRI ArcGIS 9.3 Helpdesk

3. Spatial analyses – Raster analysis

Focal

- ‘kernel’ or neighbourhood
- functions
  - sum, average, maximum, minimum, deviation

3. Spatial analyses – Raster analysis

Focal: Slope class

$$\tan S = \sqrt{\left(\frac{\delta Z}{\delta X}\right)^2 + \left(\frac{\delta Z}{\delta Y}\right)^2}$$

δZ/ δX =

-1Z	0Z	1Z
-2Z		2Z
-1Z	0Z	1Z

/8ΔX

δZ/ δY =

1Z	2Z	1Z
0Z		0Z
-1Z	-2Z	-1Z

/8ΔY

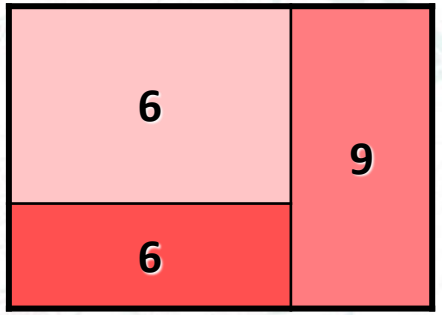
3. Spatial analyses – Raster analysis

Zonal

- Calculations for “zones”
- functions
  - sum, average, maximum, minimum, deviation

3	0	4
1	2	2
5	1	3

A	A	B
A	A	B
C	C	B



ZONALSUM

3. Spatial analyses – Raster analysis

Global

- Calculation for whole grid
- distance, viewshed, hydrological models etc.

		1

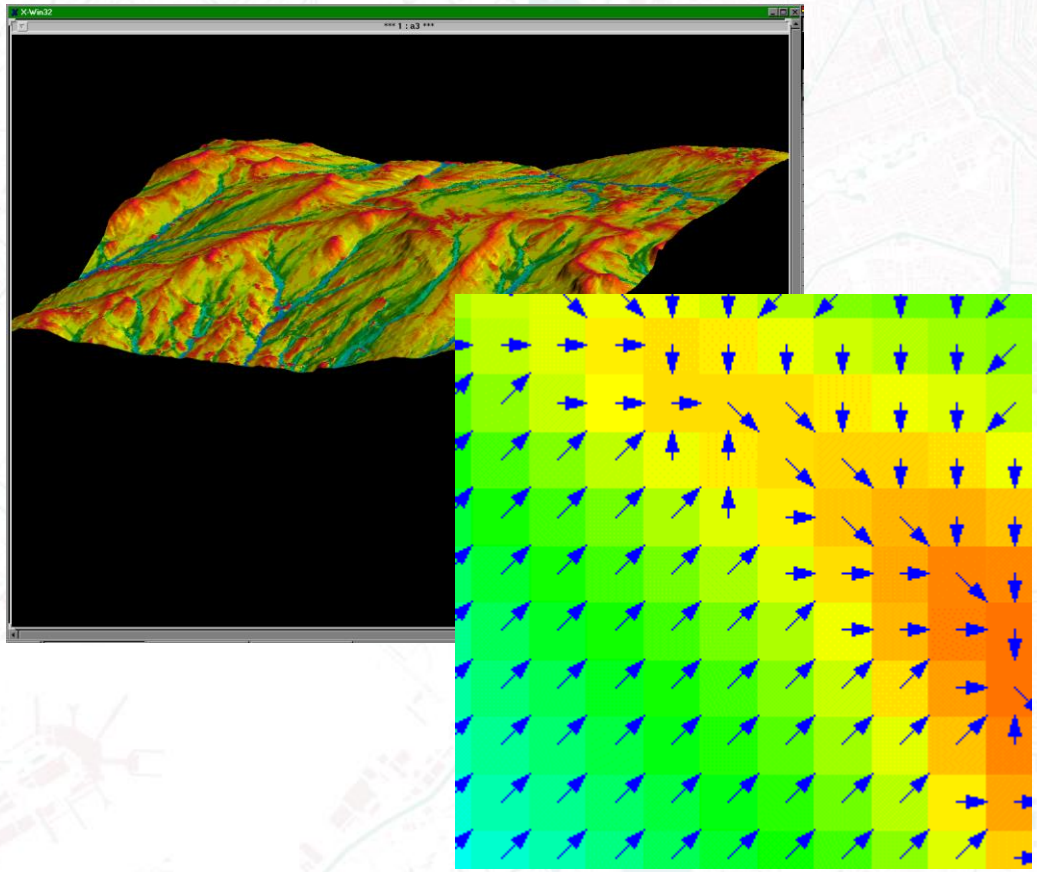
EUCLIDEAN DISTANCE

2	1	0
2,4	1,4	1
2,8	2,4	2

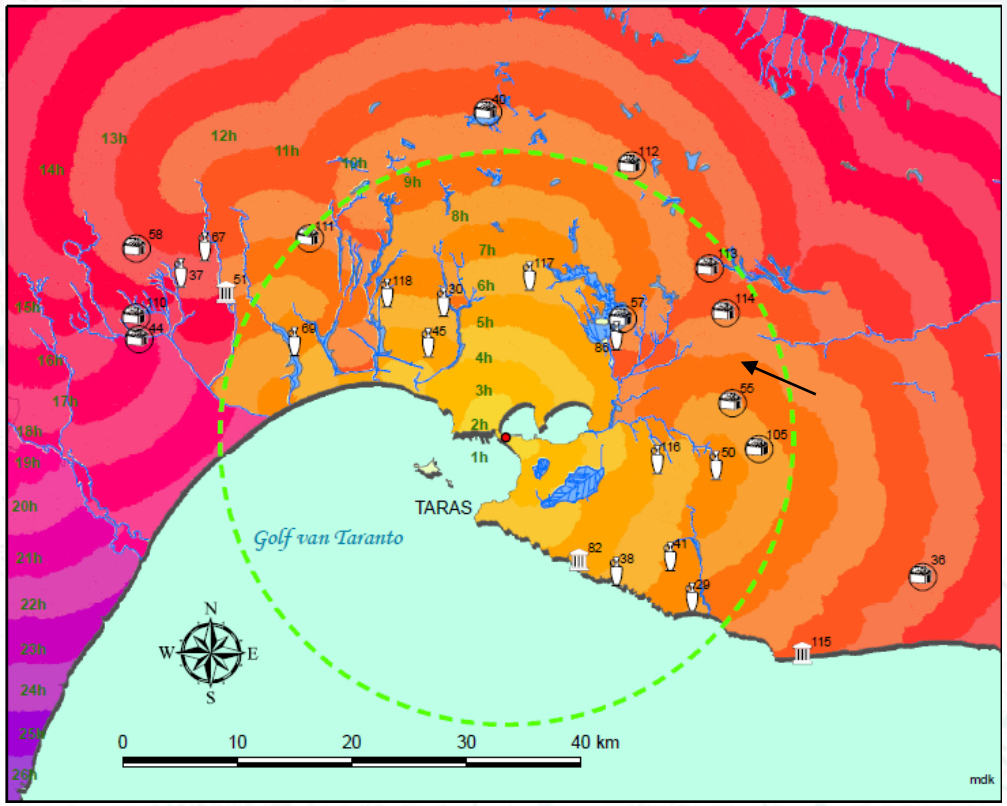
3. Spatial analyses – Raster analysis

Global: examples

Hydrological modelling



Travel time (on foot)



3. Spatial analyses – Example: Wildfires

Wildfires have been burning across Rhodes

https://news.sky.com/story/wildfires-on-rhodes-force-hundreds-of-holidaymakers-to-flee-their-hotels-12925583

https://www.esa.int/ESA_Multimedia/Images/2023/07/Rhodes_wildfire_forces_thousands_to_flee

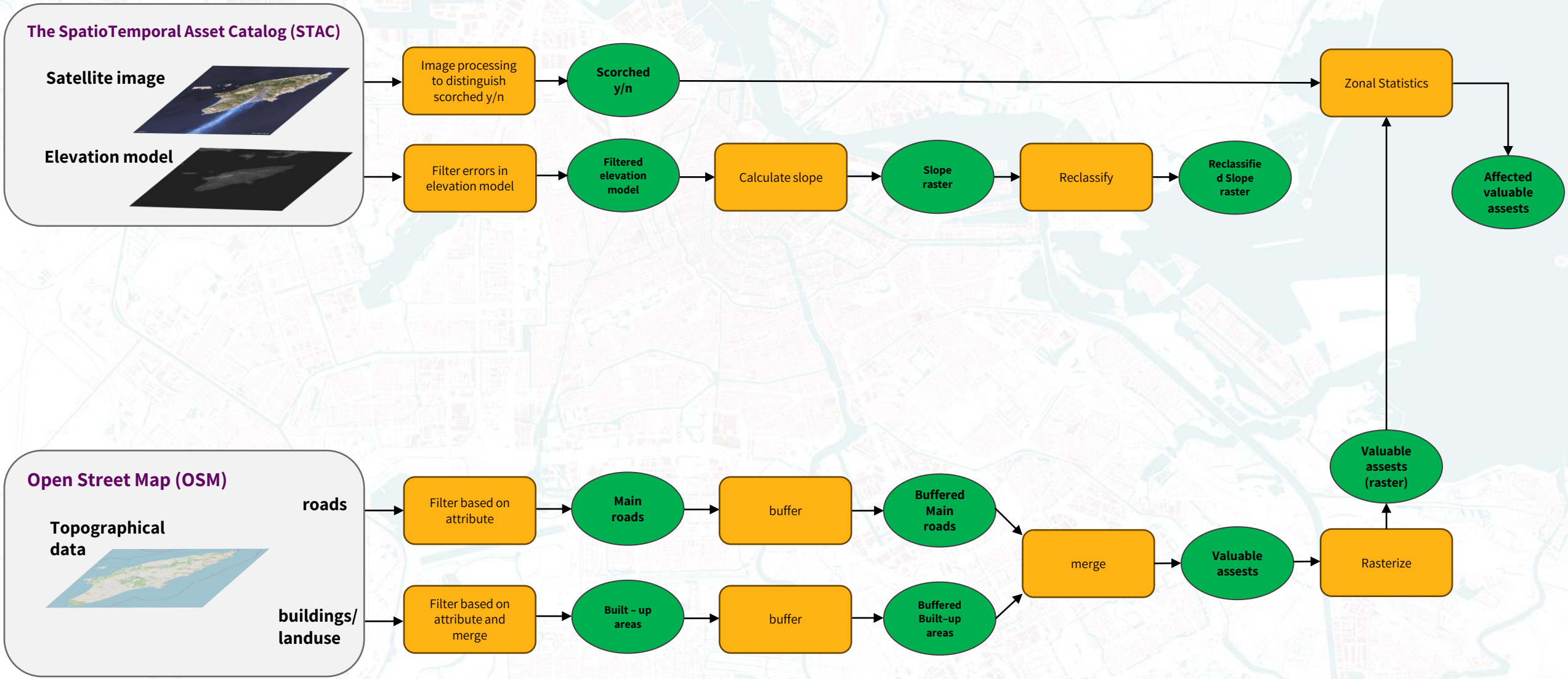
Question:

Which built-up areas are affected by the wildfire on Rhodos in the summer of 2023?

Aim:

We aim to generate a pipeline (recipe) which [1] identifies scorched areas based on satellite images and confronts this with built-up areas and infrastructures. Furthermore, **[2]** we research the relation between scorched areas and slopes.

[1] “Recipe to identify wildfire affected areas “



Structure

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4. Energy and Geographic Information Science
5. Get started - > GIS data and software

4. Energy and Geographic Information Science

Example: Site selection for windfarm
Multi Criteria Analysis

Windfarm in the UK

Selection Criteria

1. The site should be in an area of low population density (< 50 persons per km2);

2. The site should have good road access (within 1.5 km of a major road);

3. The site should not affect conservation areas and protected sites (i.e. it must be outside National Parks, Areas of Outstanding Natural Beauty (AONBs), Sites of Special Scientific Interest (SSSIs), and National Nature Reserves (NNRs));

4. The site should be flat (< 5% slope) and be no smaller than 100 ha in area.

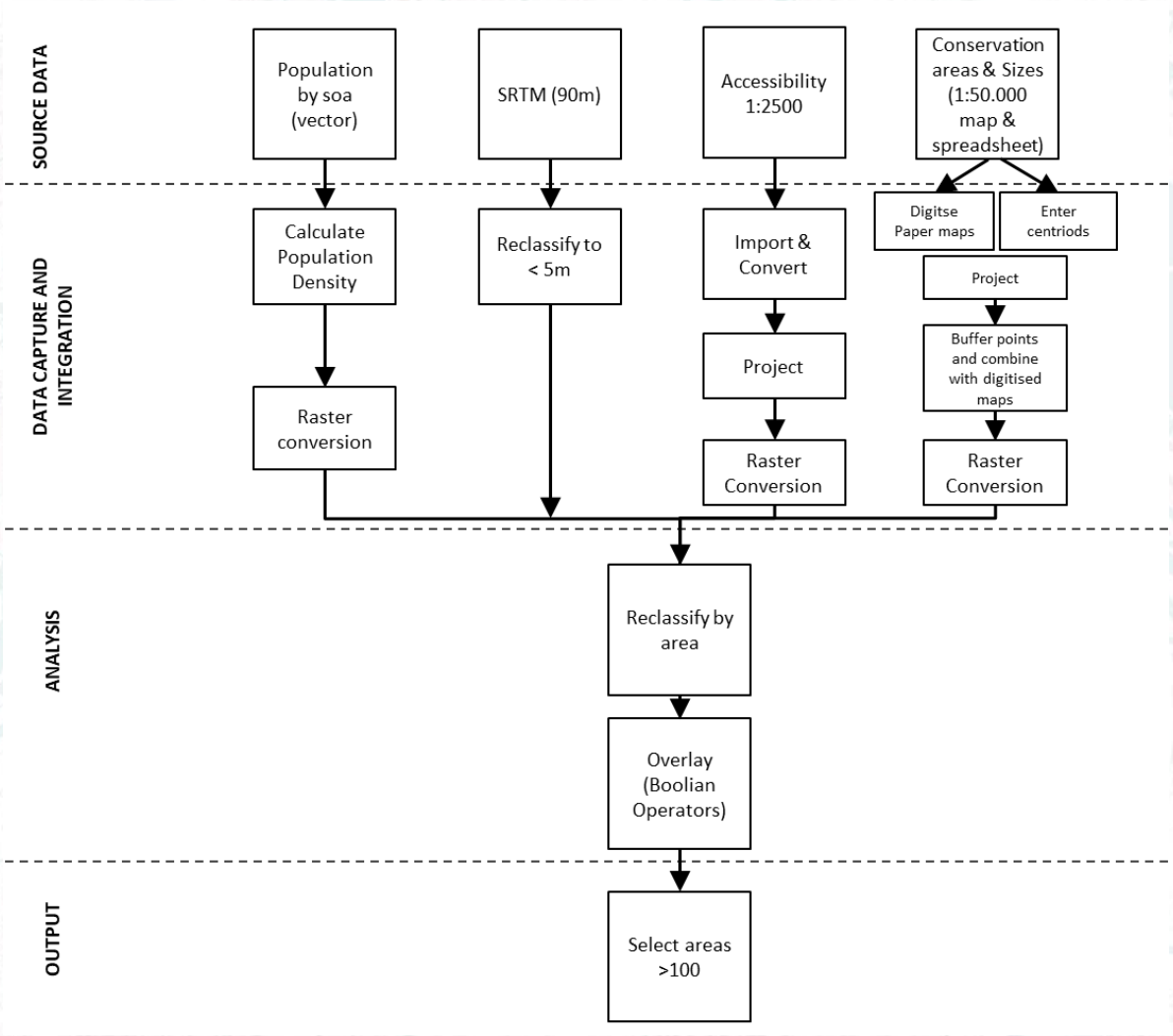
4. Energy and Geographic Information Science

Example: Site selection for windfarm
Multi Criteria Analysis

Data set	Description	Format	Year	Data creator
Population	Census population counts by Lower Super Output Areas	Digital vector polygon data set in British National Grid (BNG) co-ordinates and projection	2011	National Statistics Office
Accessibility	1:2500 roads data	Vector-based digital map database in BNG co-ordinates only	2007	Ordnance Survey
Conservation	1:50,000 map of National Park and ANOB boundaries.	Paper map of Map in BNG co-ordinates.	2005	Natural England
Conservation	1:50000, XY centroids of NNRs and SSSIs designated areas	Spreadsheet file, centroids in BNG co-ordinates only	2012	Natural England
Elevation	SRTM (Shuttle Radar Topography Mission) DEM – 90 metre spatial resolution	GeoTIFF image geometrically corrected to BNG co-ordinates	2000	NASA (National Aeronautics and Space Administration)

4. Energy and Geographic Information Science

Example: Site selection for windfarm
Multi Criteria Analysis

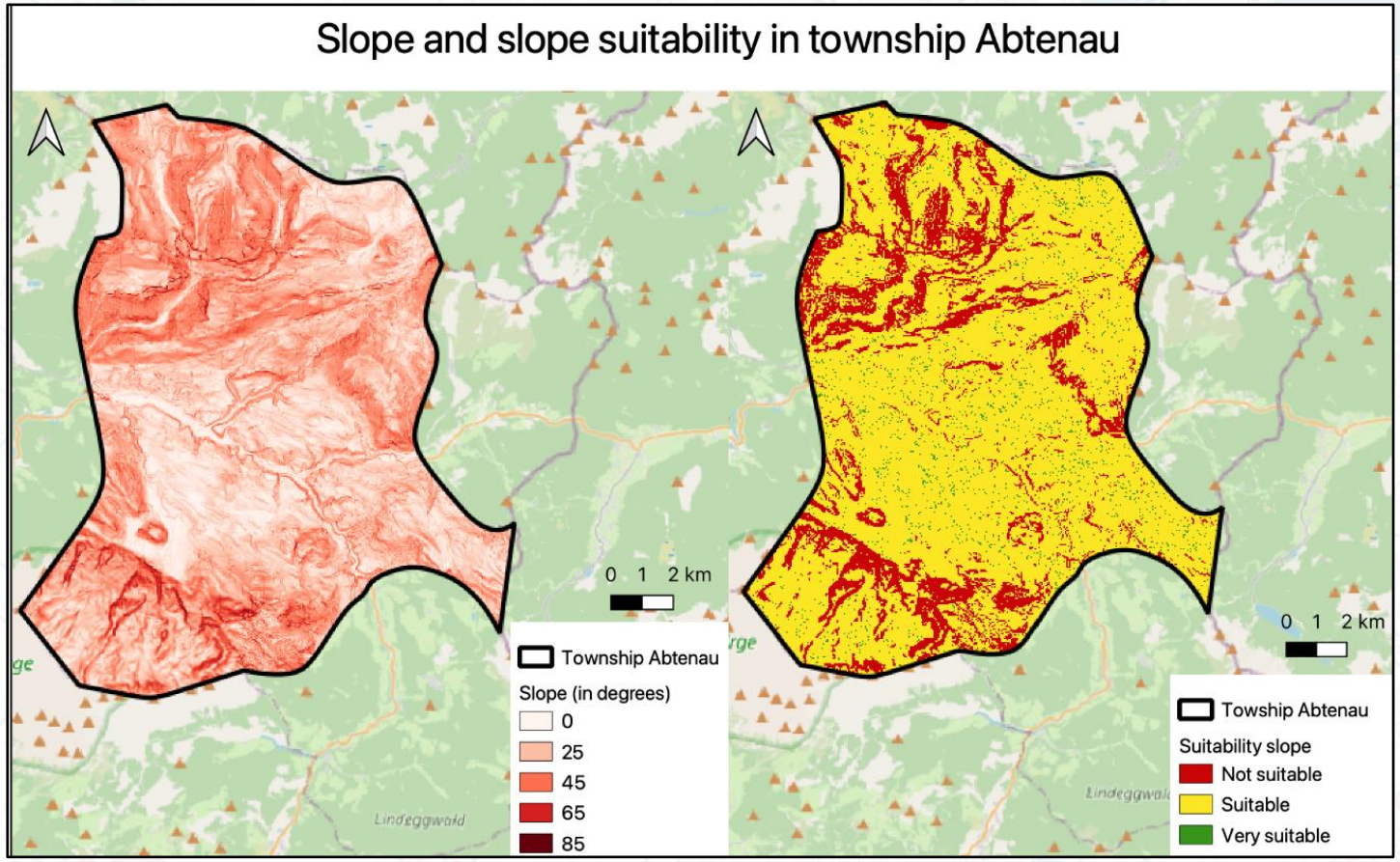


4. Energy and Geographic Information Science

Example: Site selection for windfarm
Multi Criteria Analysis

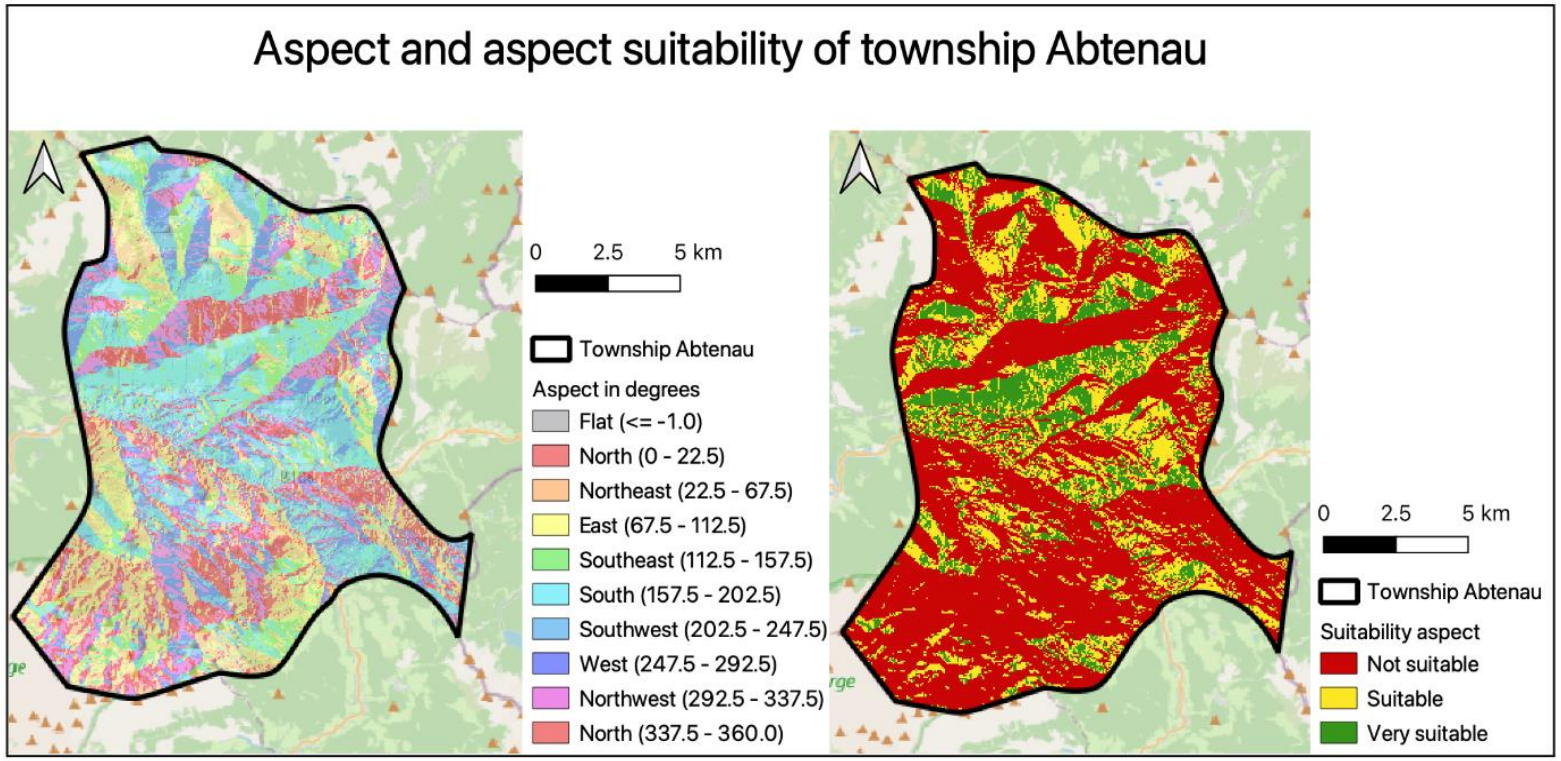
4. Energy and Geographic Information Science

Example: Site selection for solar panels - *Multi Criteria Analysis*



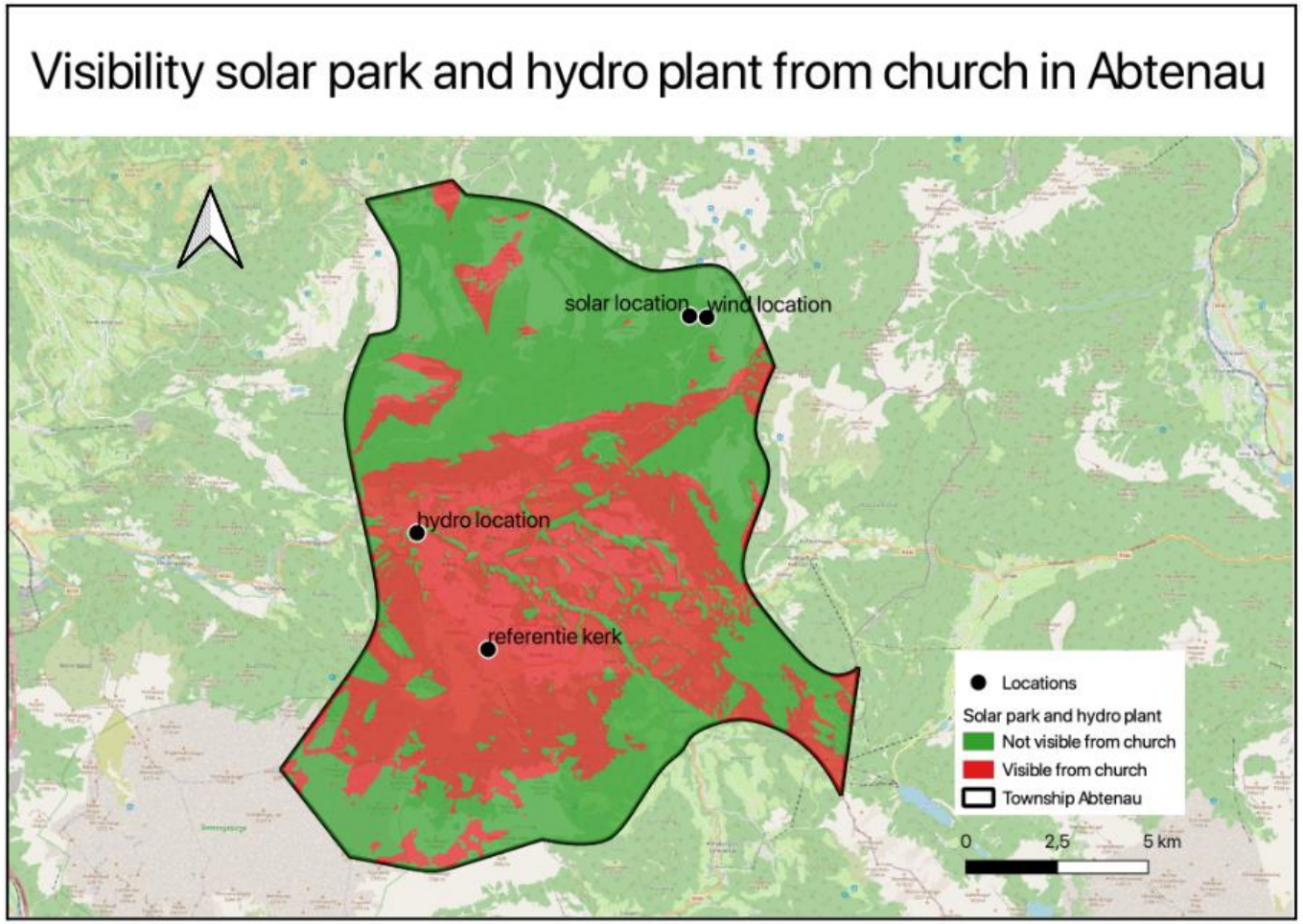
4. Energy and Geographic Information Science

Example: Site selection for solar panels - *Multi Criteria Analysis*



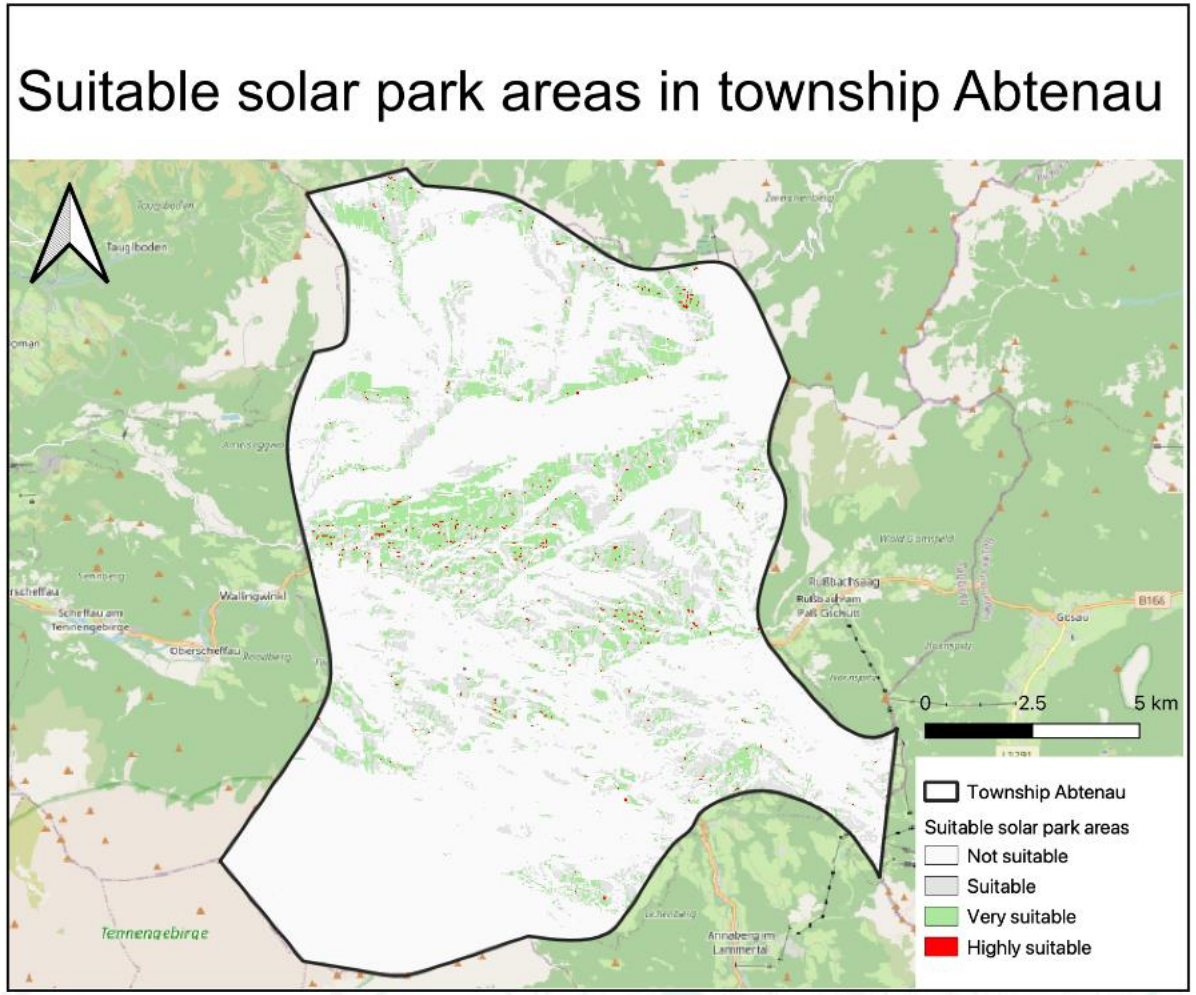
4. Energy and Geographic Information Science

Example: Site selection for solar panels - *Multi Criteria Analysis*



4. Energy and Geographic Information Science

Example: Site selection for solar panels - *Multi Criteria Analysis*

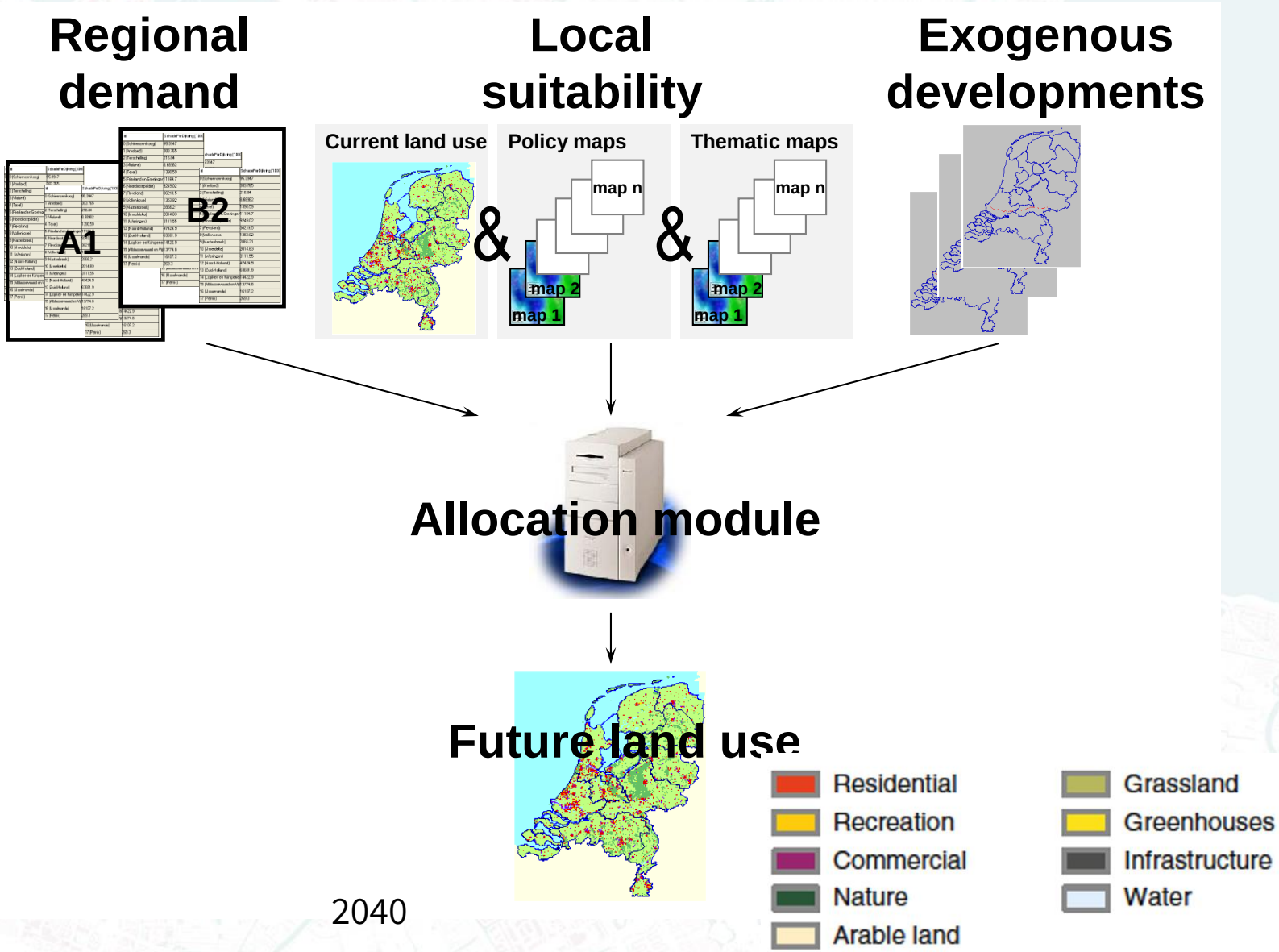


4. Energy and Geographic Information Science

Land use modelling

Land use

Social economic scenarios
Climate change



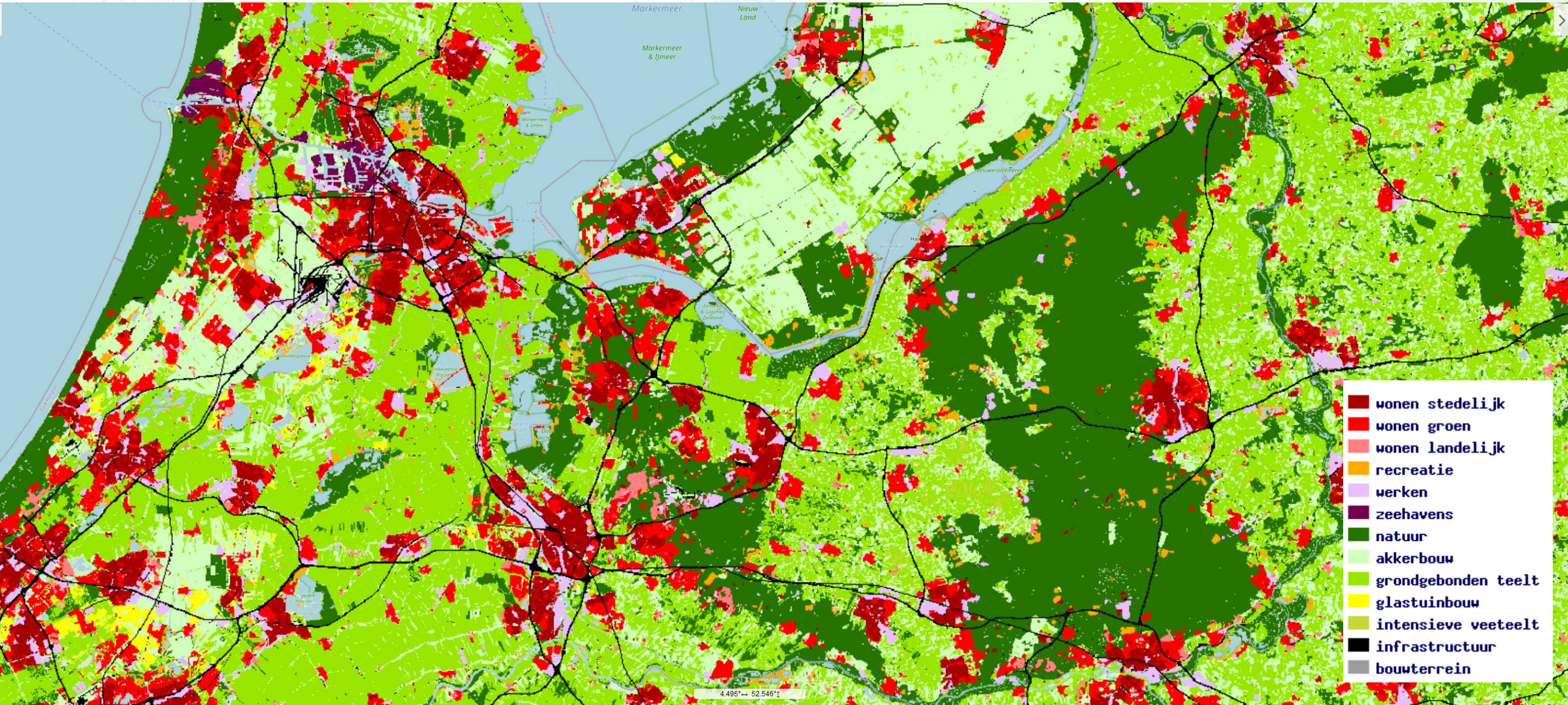
2010

2040

4. Energy and Geographic Information Science

Land use modelling – scenario based

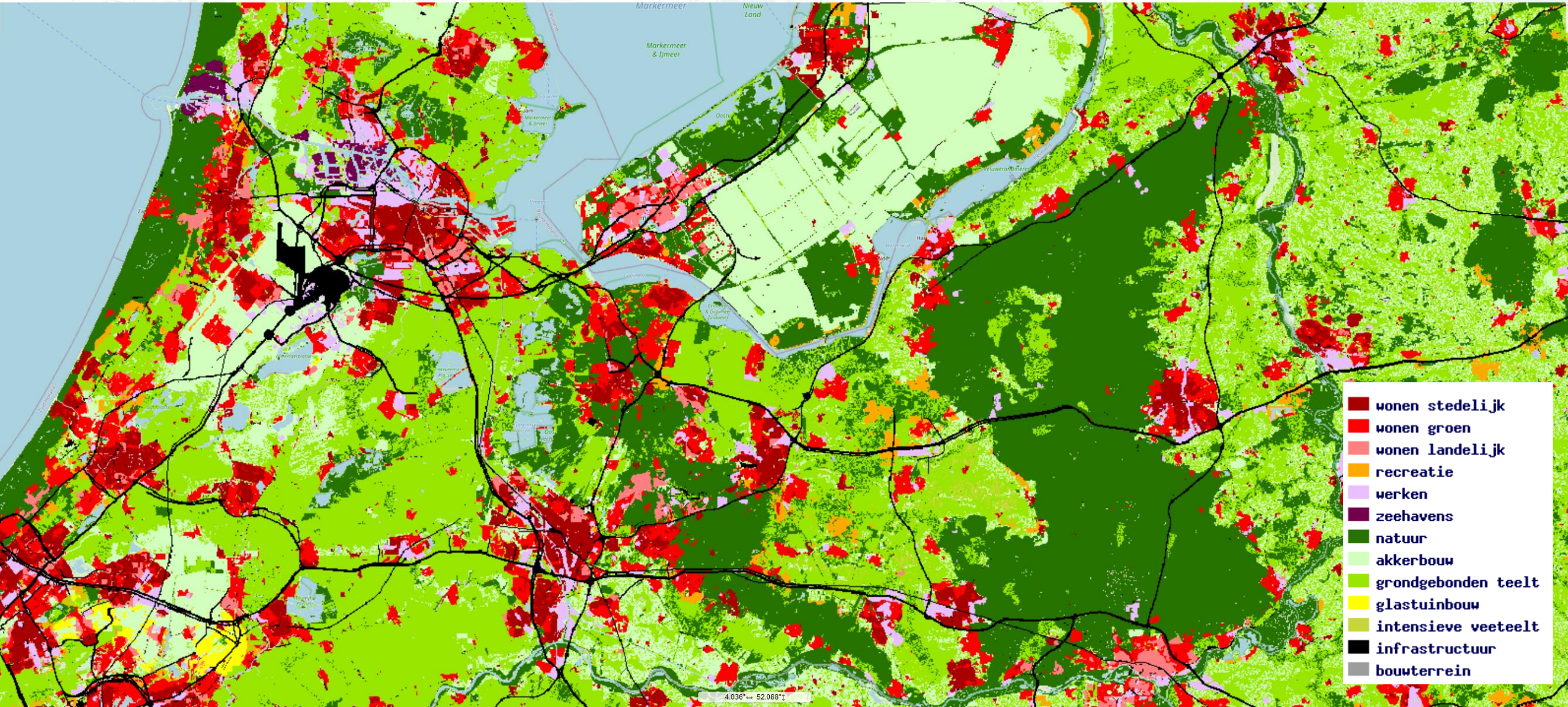
2010



4. Energy and Geographic Information Science

Land use modelling – scenario based

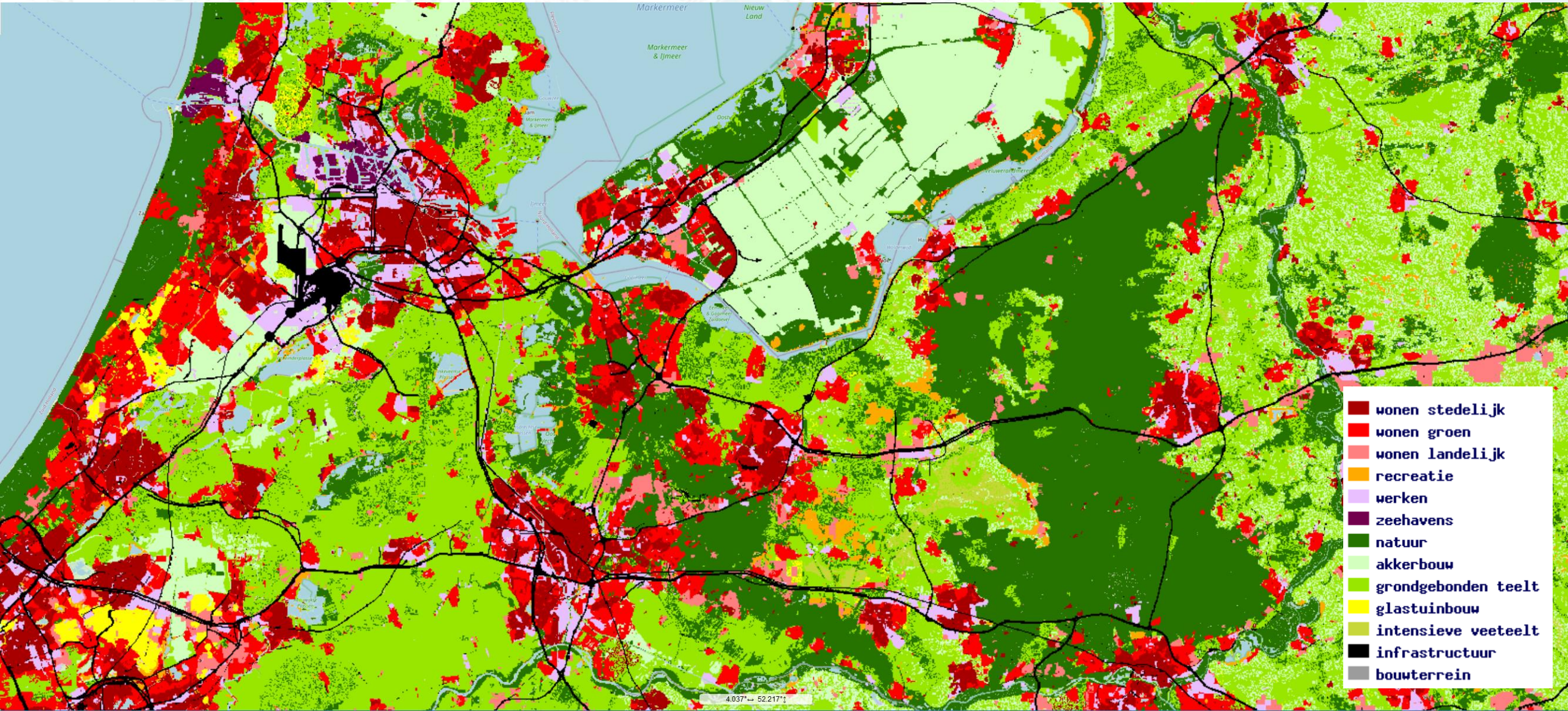
2040 – minimal growth scenario



4. Energy and Geographic Information Science

Land use modelling – scenario based

2040 maximum growth scenario



4. Energy and Geographic Information Science

- Distance to power grids
- Distance to industry
- Distance to residential areas
- Distance to powerplants
- Solar panels, windturbines etc.

- Flood risks
- Accessibility
- Defensibility etc.

- *Probably most of the time*

"Multi Criteria Analysis"

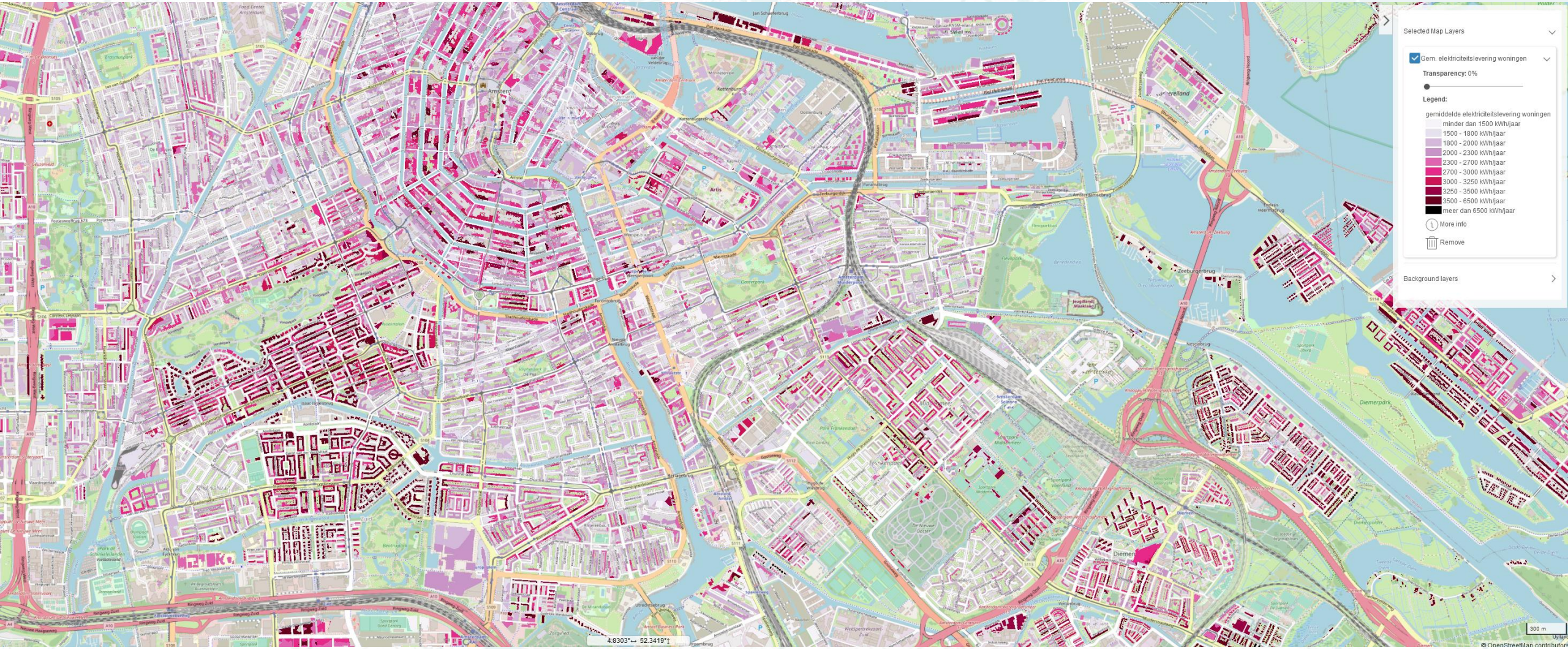
- *Beware of data quality issues*

- different scales (spatial and temporal
- different purposes

"Modifiable Areal Unit Problem"

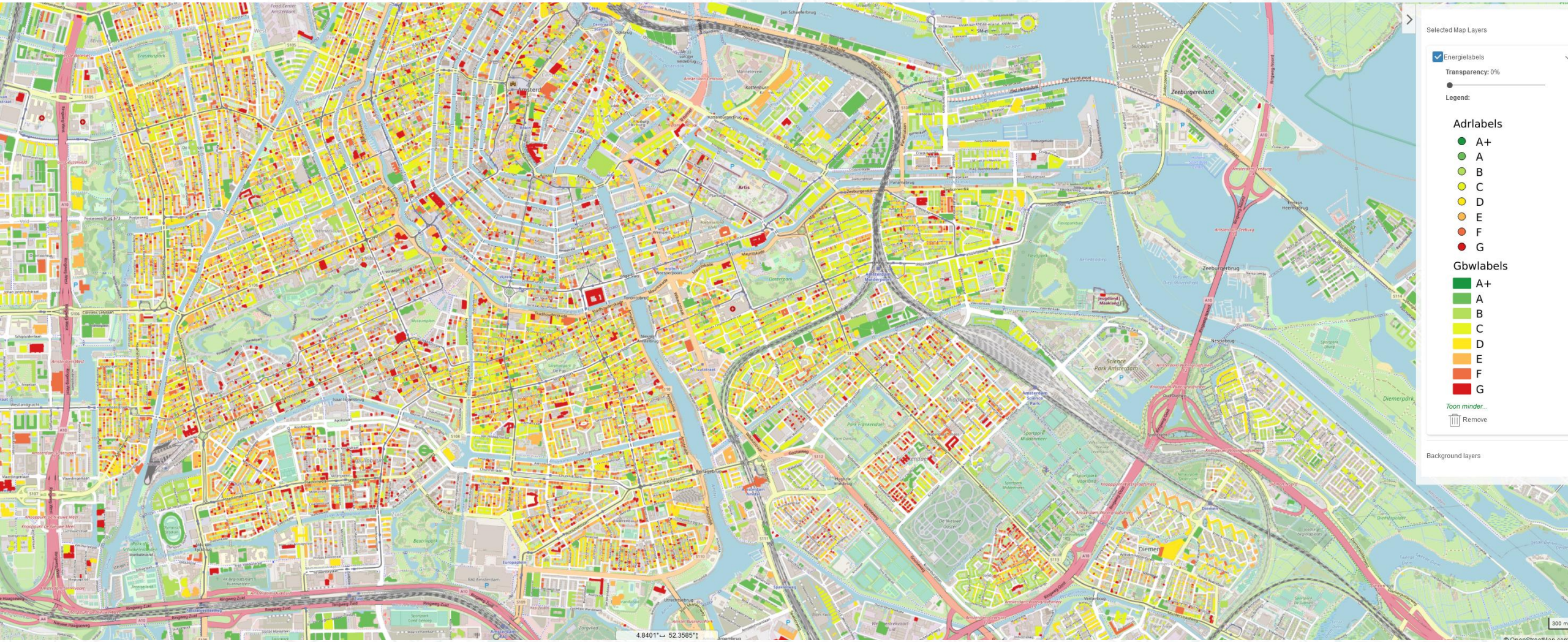
4. Energy and Geographic Information Science

Energy supply (PDOK/Edugis)



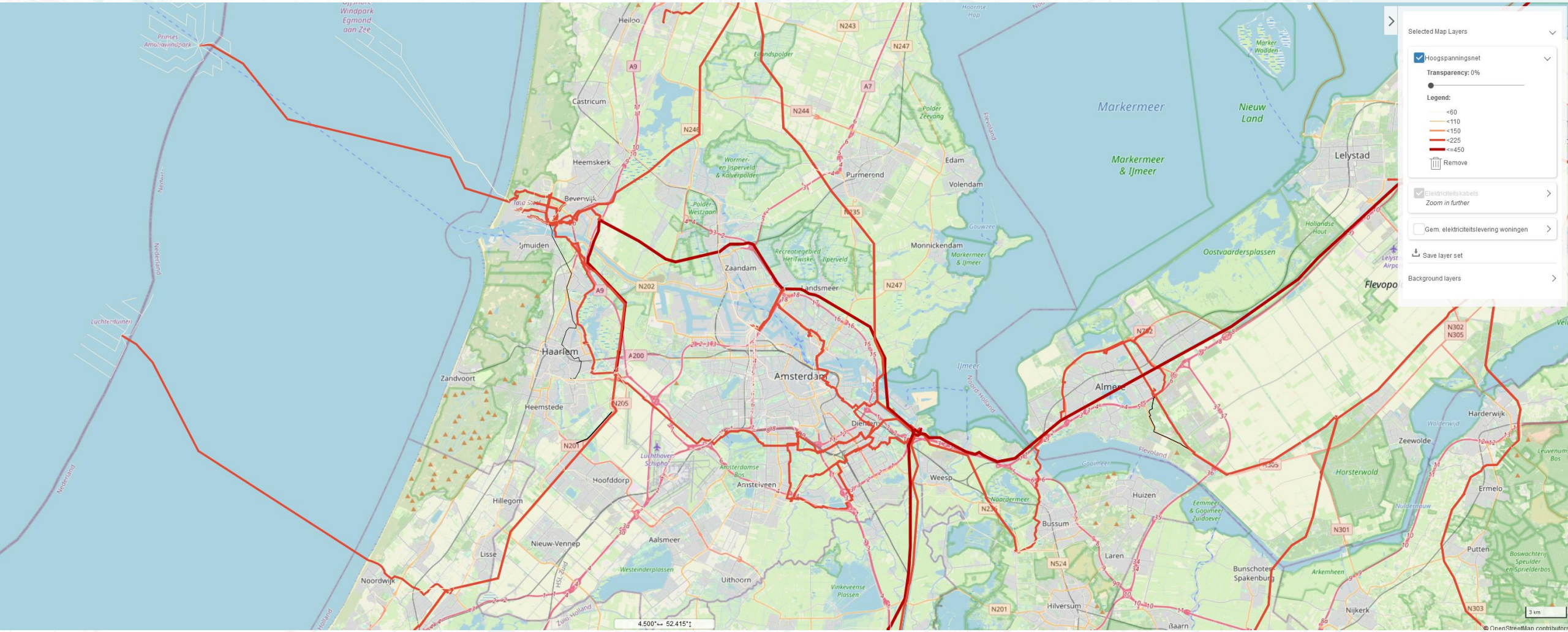
4. Energy and Geographic Information Science

Energy labels (PDOK/Edugis)



4. Energy and Geographic Information Science

High-voltage grid (PDOK/Edugis)



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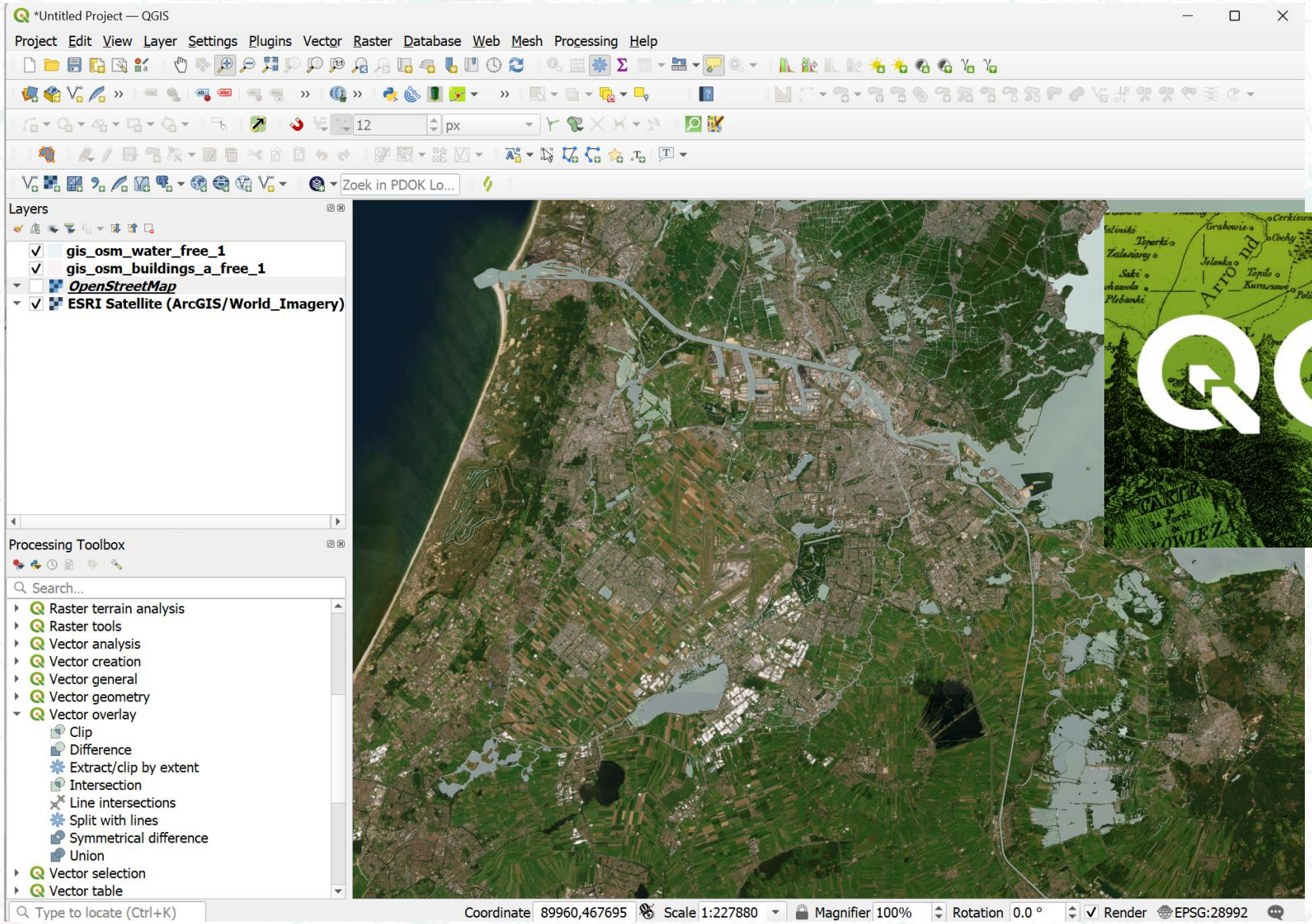
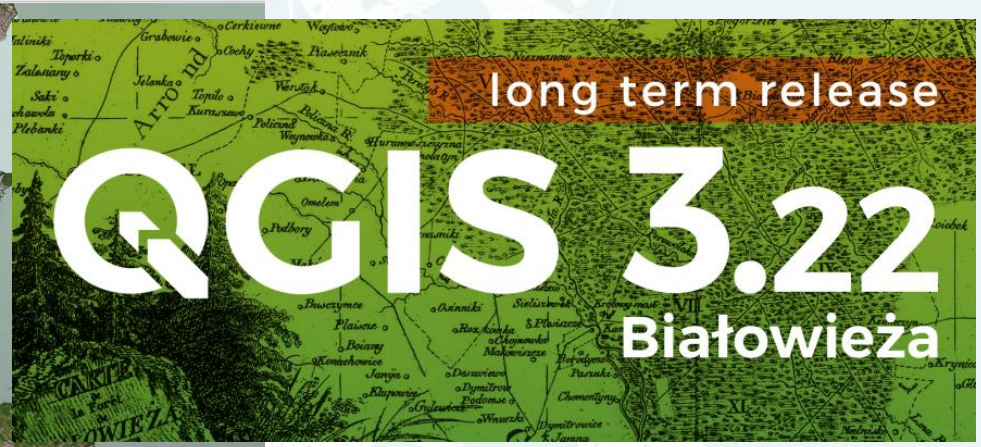
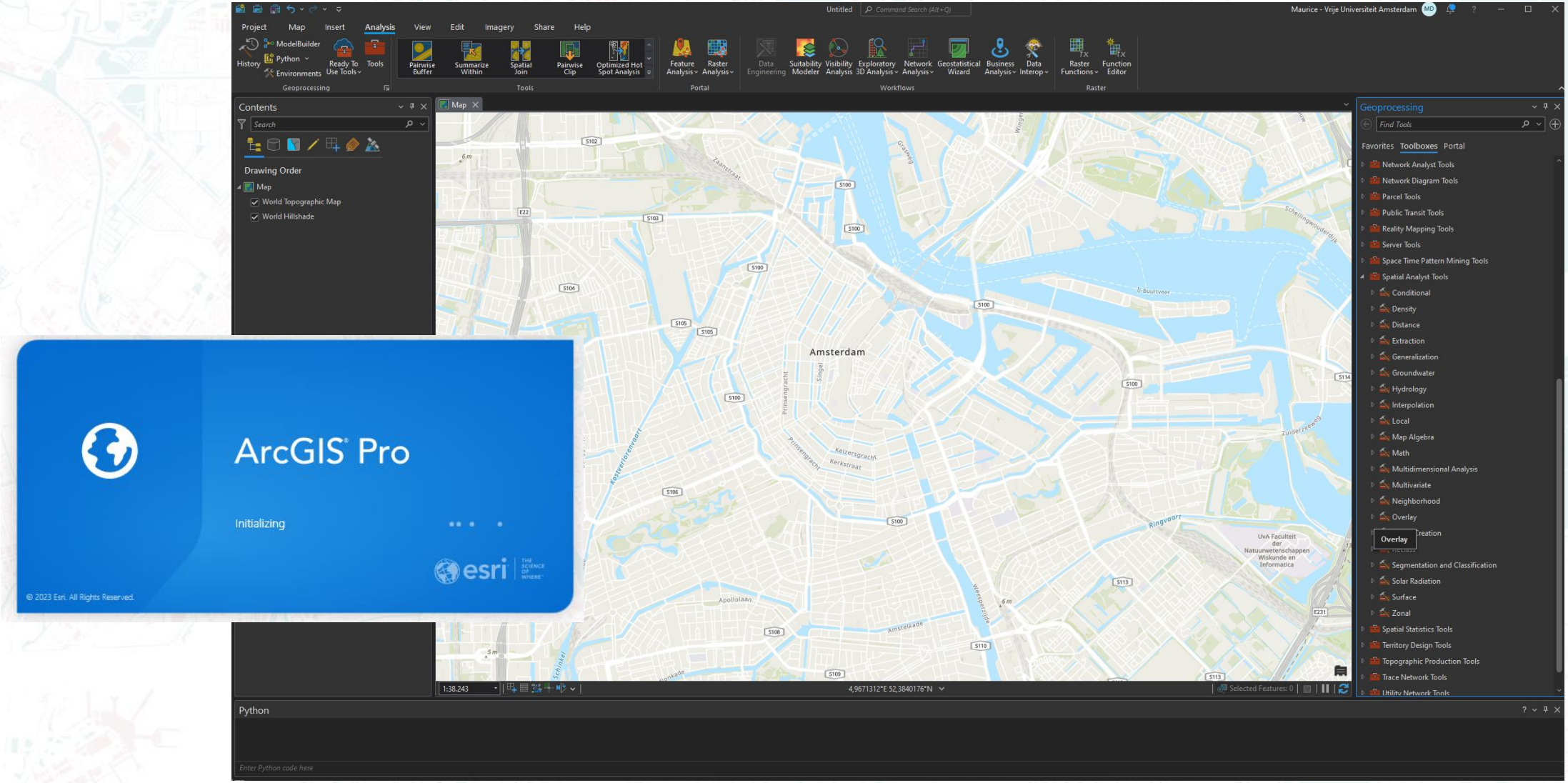
5. Getting started with GIS software en data





5. Getting started with GIS software en data



5. Getting started with GIS software en data

The Geospatial **(PYTHON)** Landscape

- Open satellite data access: ***pystac_client***, ***pystac***
- Work with raster: ***rioxarray, xarray-spatial***
- Work with vector: ***geopandas***
- ~~*Proprietory software:* ***arcpy*** *~ both raster and vector*~~

STAC
SpatioTemporal Asset Catalog

xarray

GeoPandas

~~ArcPy~~

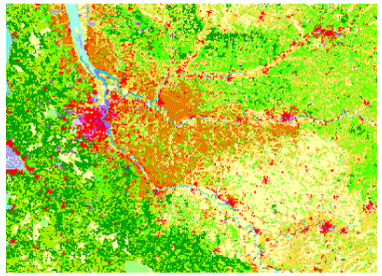
5. Getting started with GIS software en data

CORINE Land Cover 2018 (vector/raster 100 m), Europe, 6-yearly

General Info

Download

Provides pan-European CORINE Land Cover inventory for 44 thematic classes for the 2018 reference year. The dataset has a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a Minimum Mapping Width (MMW) of 100 m for linear phenomena and is available as vector and as 100 m raster data.



Validation status

Validated

Dataset citation

- **DOI (raster 100 m):** https://doi.org/10.2909/960998c1-1870-4e82-8051-6485205ebbac
- **DOI (vector):** https://doi.org/10.2909/71c95a07-e296-44fc-b22b-415f42acfdf0

https://land.copernicus.eu/en/products/corine-land-cover/clc2018?tab=download

5. Getting started with GIS software en data

https://ghsl.jrc.ec.europa.eu/visualisation.php#

5. Getting started with GIS software en data

European Commission

Joint Research Centre Data Catalogue

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COLLECTION

River Flood Hazard Maps at European and Global Scale

Acronym: FLOODS

PAGE CONTENTS

Description

Contact

Datasets

Realated resources

Additional information

Description

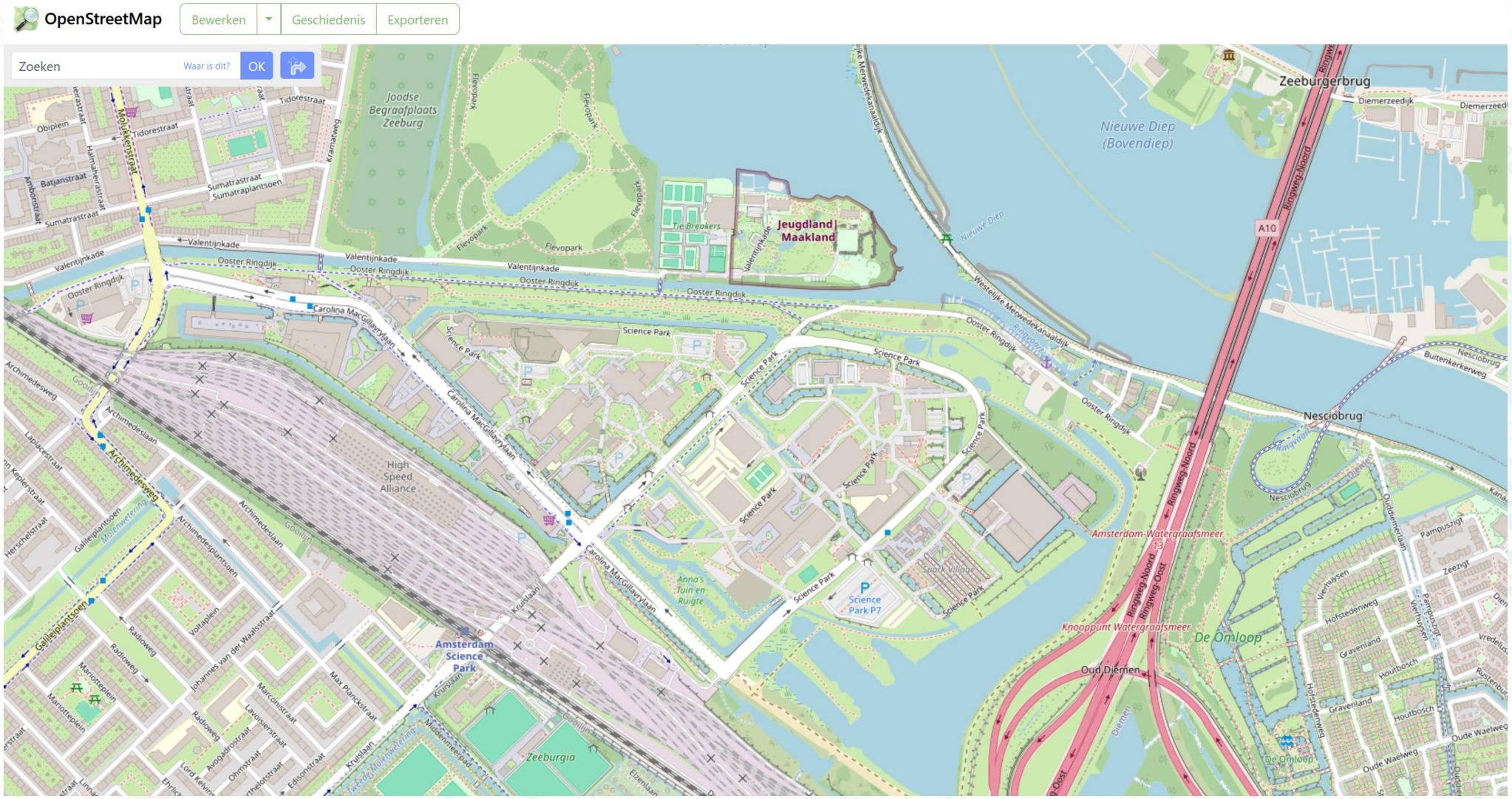
The datasets included in this collection depict flood prone areas in Europe and the World for river flood events of different magnitude

(from 1-in-10-year to 1-in-500-year). The maps have been developed using hydrological and hydrodynamic models, driven by the climatological data of the European and Global Flood Awareness Systems (EFAS and GloFAS). European-scale maps comprise most of the geographical Europe and all the river basins entering the Mediterranean and Black Seas in the Caucasus, Middle East and Northern Africa countries.

All maps are in raster format (GEOTIF) with a grid resolution of 100m (European-scale maps) and 30 arcseconds (global-scale maps). The maps can be used to assess the exposure of population and economic assets to river floods, and to perform flood risk assessments. More information can be found in the references mentioned in the description of each dataset. The collection also includes supplementary maps showing the river network and the water bodies considered in the creation of the flood maps IMPORTANT NOTE: all the maps in this collection are based on JRC elaborations and are not official flood hazard maps (for details and limitations please refer to related publications).

https://data.jrc.ec.europa.eu/collection/id-0054

5. Getting started with GIS software en data

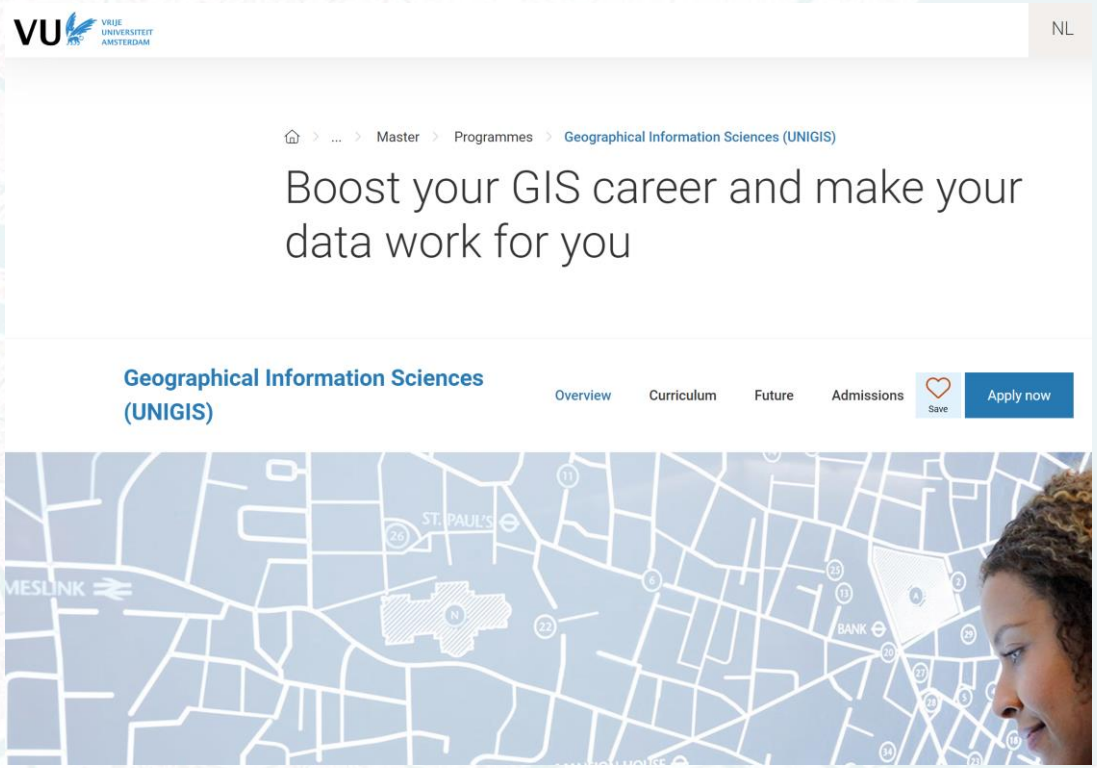


https://www.openstreetmap.org/#map=16/52.3532/4.9649

https://download.geofabrik.de/

Thanks!

https://www.esciencecenter.nl/events/?f=workshops



https://vu.nl/en/education/master/geographical-information-sciences

You can always reach out to me!

m.dekleijn@esciencecenter.nl