ECAP

Prague Training Visit

19.09.2016 – 23.09.2016

BOKU

Department of Landscape, Spatial and Infrastructure Sciences

Remote Sensing and GIS as tools for Sustainable Land Management

BOKU University of Natural Ressources and Life Sciences, Vienna
Institute of Surveying, Remote Sensing and Land Information

Gerald LINDNER

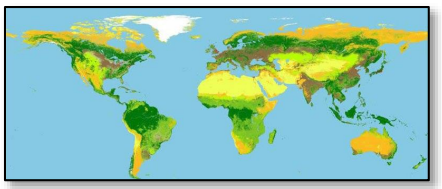
Overview

1. Introduction to Remote Sensing

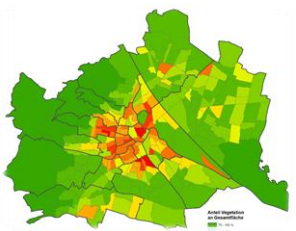
2. Introduction to GIS

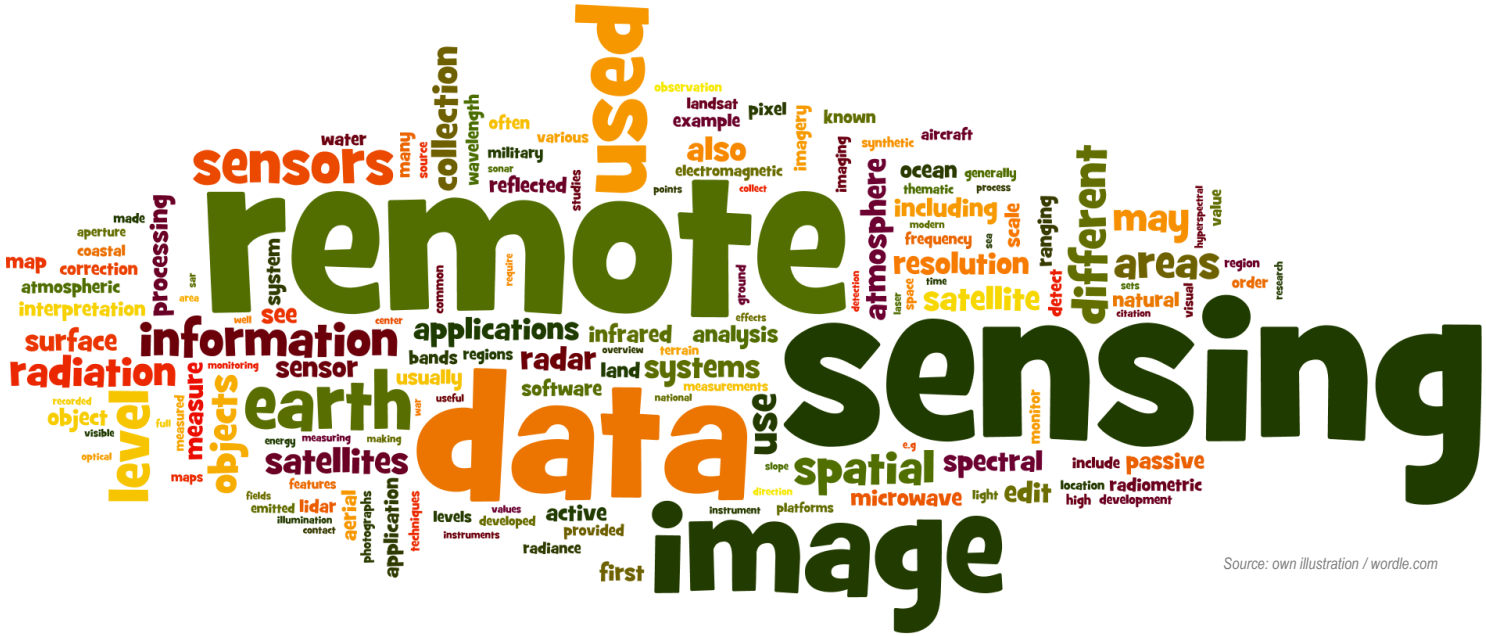
3. National Spatial Infrastructure in Austria

4. Land Cover Mapping



5. Indicators

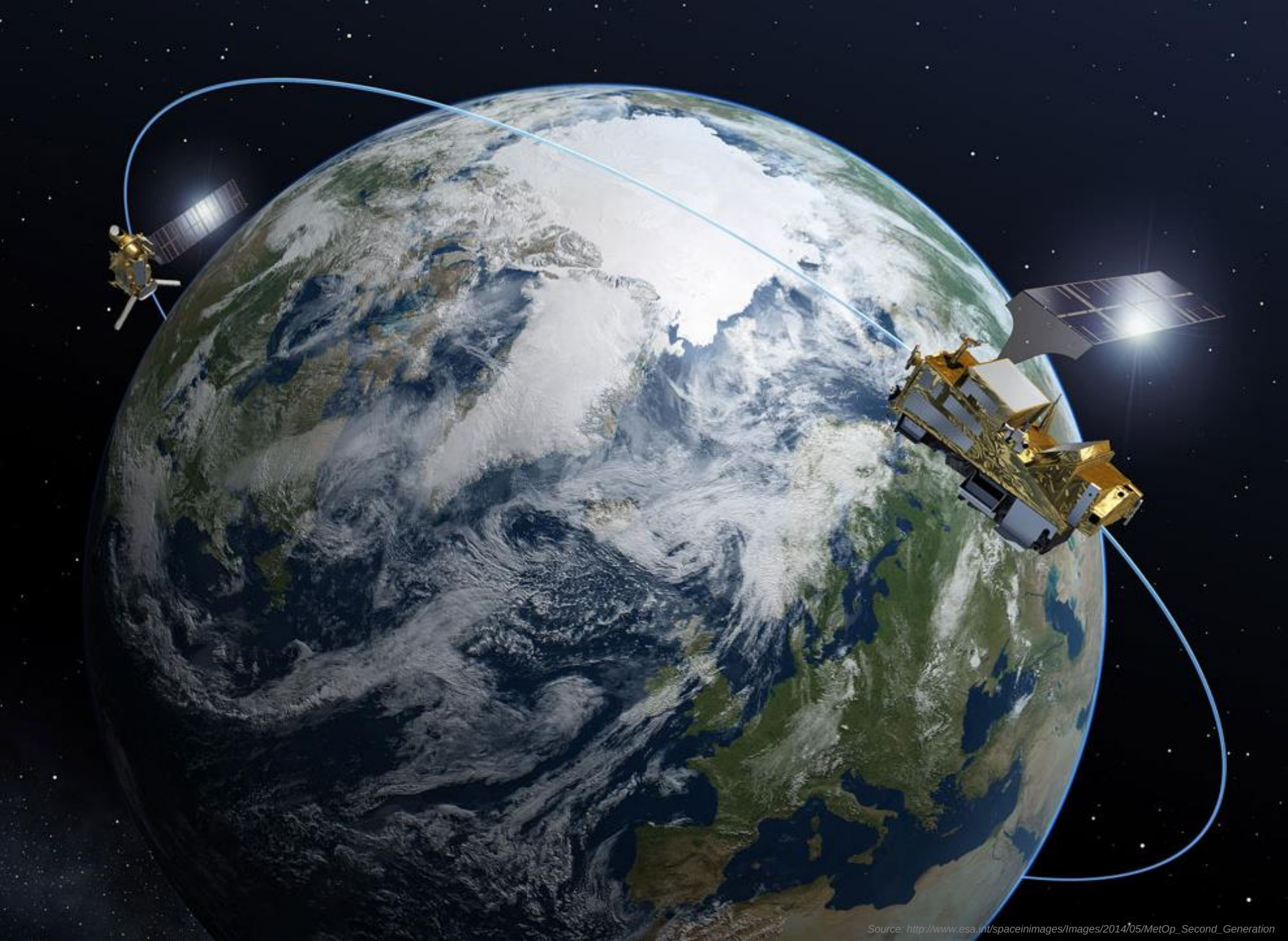




Source: own illustration / wordle.com

1. INTRODUCTION TO REMOTE SENSING

- What & Why?
- Platforms
- Sensors & Products
- Data



Source: http://www.esa.int/spaceinimages/Images/2014/05/MetOp_Second_Generation

Source: http://forum.xcitefun.net/do-u-know-how-many-artificial-satellites-surround-earth-t67552.html

The Earth as Art

Source: http://www.nasa.gov

U.S. Department of the Interior
U.S. Geological Survey

Yukon Delta

After beginning in northern British Columbia and flowing through Yukon in Canada, the Yukon River crosses Alaska, USA, before emptying into the Bering Sea. Countless lakes, sloughs, and ponds are scattered throughout this scene of the Yukon Delta. The river's sinuous, branching waterways seem like blood vessels branching out to enclose an organ. It is one of the largest river deltas in the world, and currently (2010) protected as part of the Yukon Delta National Wildlife Refuge.

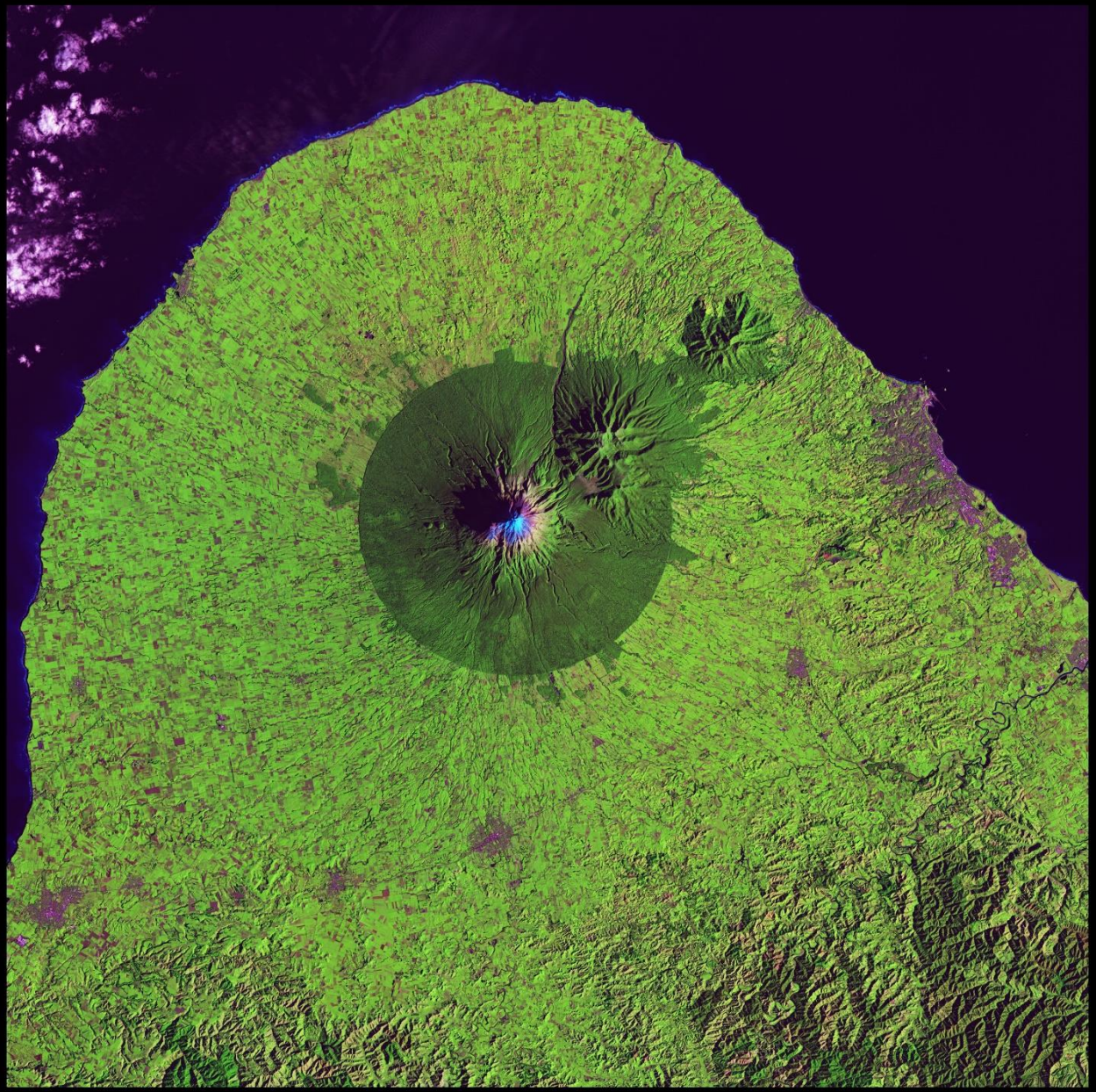
Landsat 7 data acquired on 09/22/2002

USGS science for a changing world

NASA

USGS
science for a changing world

NASA



U.S. Department of the Interior
U.S. Geological Survey

Mount Taranaki

A nearly perfect circle of forest delineates the boundary of Egmont National Park in New Zealand. Snow-capped Mount Taranaki marks the center of the park, which is surrounded by green farmland.

Landsat 8 data acquired on 06/01/2014

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NASA

U.S. Department of the Interior
U.S. Geological Survey

Nature's Patterns

The biologically complex conditions of mangroves are shown in dark green along the fingers of the Ord River in Australia. Yellow, orange, and blue represent the impressive flow patterns of sediment and nutrients in this tropical estuary. The bright spot at the lower left is an area of mudflats, which is home to saltwater crocodiles.

Landsat 8 data acquired on 05/12/2013

USGS
science for a changing world

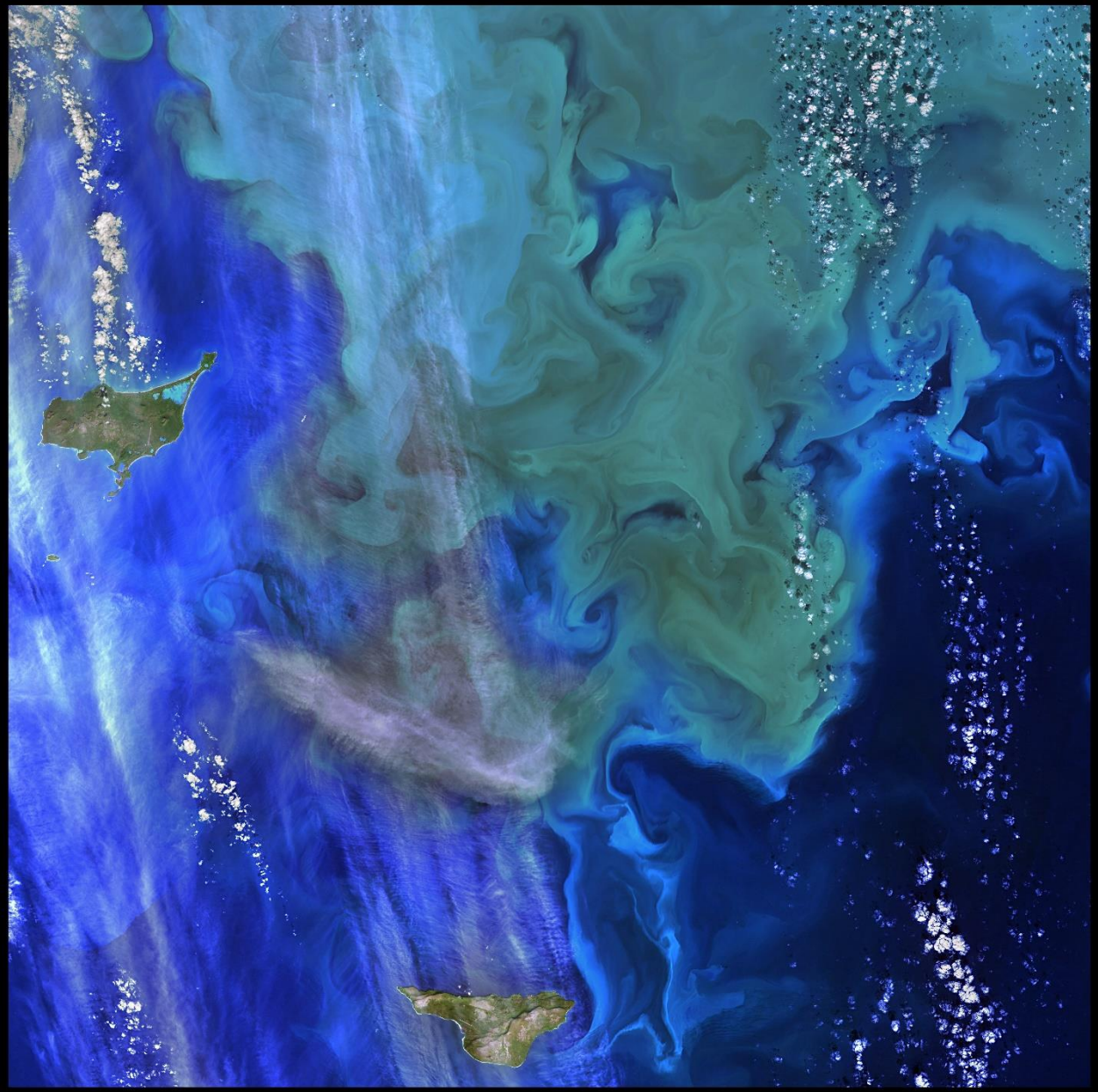
NASA

U.S. Department of the Interior
U.S. Geological Survey

Life along the Nile

It is easy to see from this image why people have been drawn to the Nile River in Egypt for thousands of years. Green farmland marks a distinct boundary between the Nile floodplain and the surrounding harsh desert.

Landsat 8 data acquired on 08/15/2014



U.S. Department of the Interior
U.S. Geological Survey

Earth's Aquarium

These green and blue swirls in the Bering Sea reveal the bottom of the food chain in the ocean. Microscopic organisms called phytoplankton, which are important to fish populations, may be too small to be seen individually, but in vast numbers they are visible from space. The white clouds in the image look like bubbles in an aquarium.

Landsat 8 data acquired on 09/22/2014

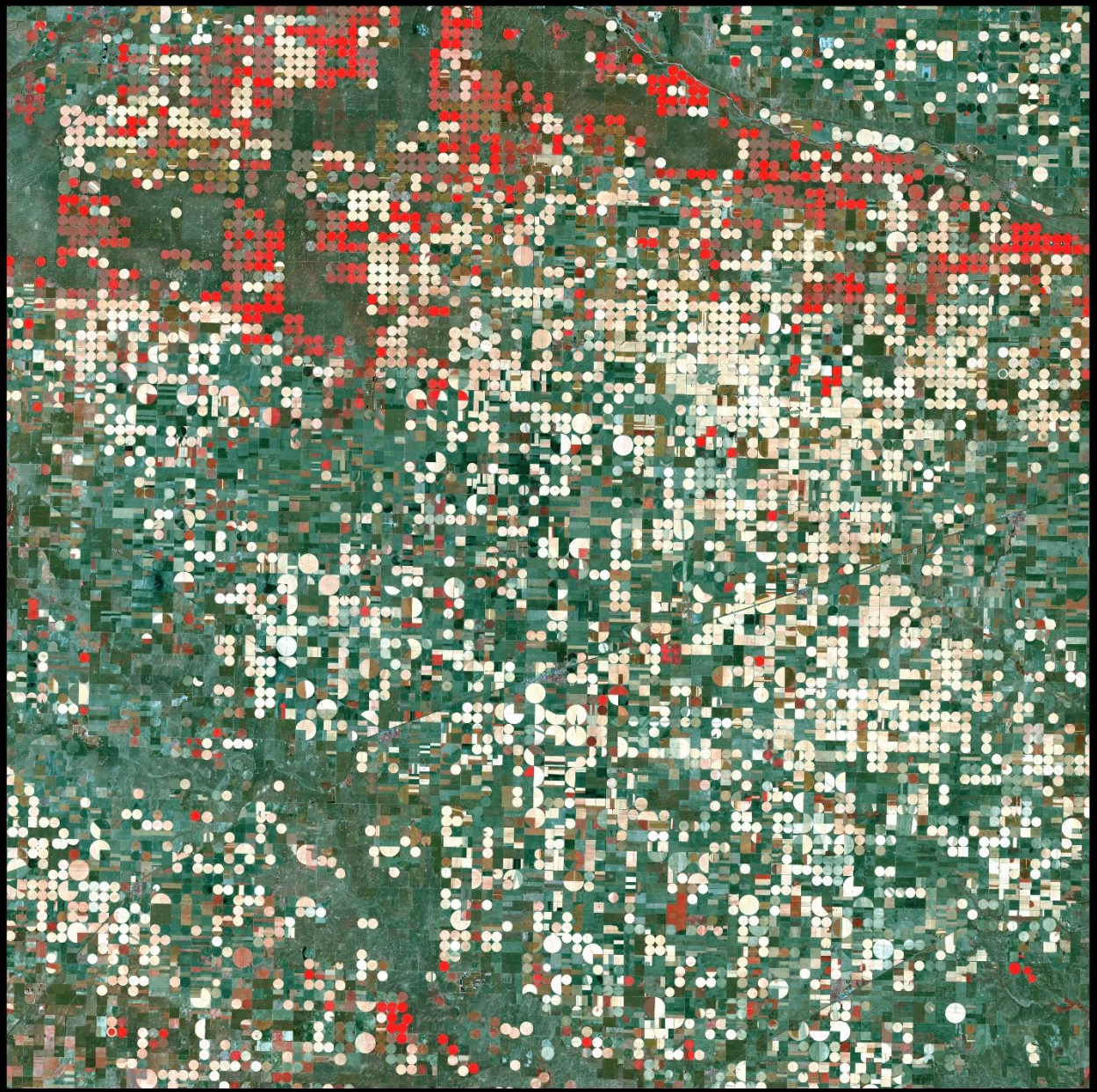
U.S. Department of the Interior
U.S. Geological Survey

Garden City, Kansas

Center pivot irrigation systems created these circular patterns in crop land near Garden City, Kansas. The red circles indicate irrigated crops of healthy vegetation. The light-colored circles represent harvested crops.

Landsat 7 data acquired 9/25/2000

1" = 2.2 miles (3.5 km)



USGS science for a changing world

NASA

What?

Traditionally:

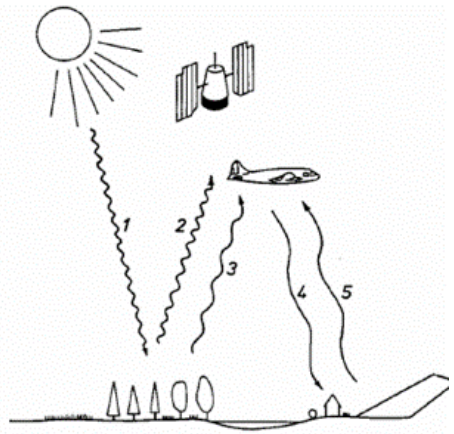
"Remote sensing is the acquisition of information about an object by a recording device that is **not in physical contact** with it."

Today:

"…the process of collecting, viewing, interpreting, and analyzing aerial or satellite-based images and geodata."

Distinction of methods of Remote Sensing:

- radiation path (passive & active)
- platform (satellite, plane, UAV, terrestrial)
- sensor



Why?

in general:

- Environment Analysis
- Civil Engineering
- Disaster Management / Risk analysis
- Urban Planning / Growth
- Rural Planning
- …

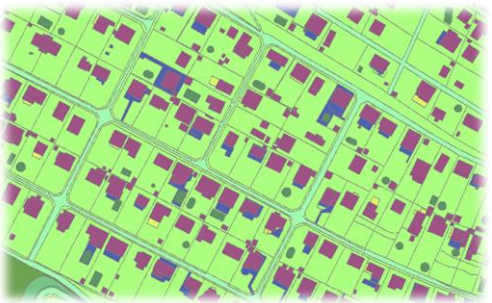
Need for…

…Remote Sensing Data

in different scales / resolutions

in Sustainable Land Management:

- Monitoring of spatial and temporal environment changes (Land Cover, Land Use)

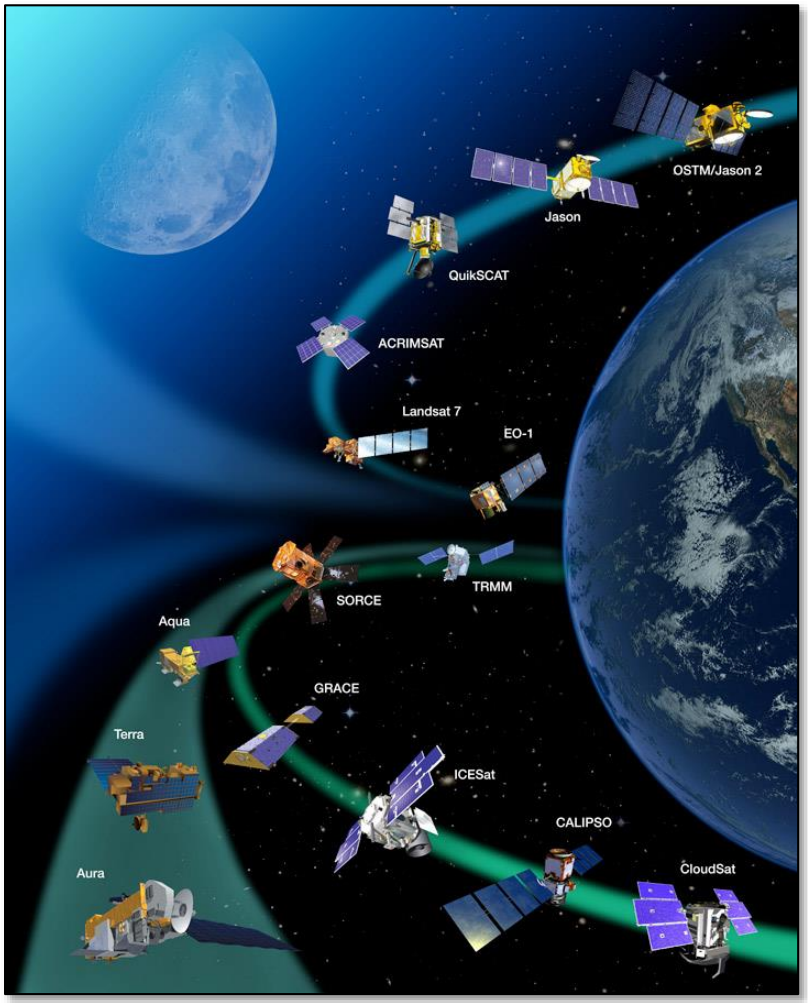


More applications later on…

Platforms

- **Satellites with commercially available data**
  - AVHRR *(1100 m resolution)*
  - ASTER *(15 m resolution)*
  - RapidEye *(6.5 m resolution)*
  - Pleiades *(0.7 m resolution)*
  - Worldview-3 *(0.31 m resolution)*
  - …
- **Satellites with free data**
  - Landsat *(30 m resolution)*
  - Sentinel-2 *(10 m resolution)*
- **Aircrafts** *(up to 5 cm resolution)*
  - Planes
  - Helicopters
- **UAVs (Unmanned Aerial Vehicles)** *(up to sub-millimeter resolution)*
  - Fixed-wing
  - Rotary-wing
  - Balloons
  - Kites

Platforms



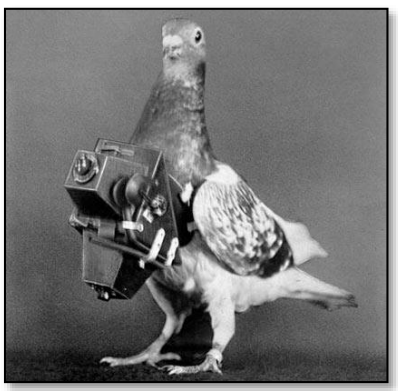
Source: http://spacereal.ru/sputniki-planety-zemlya/

Source: http://www.luftbild-salzburg.com/img/remos1.jpg

Source: http://www.luftbild-salzburg.com/img/trike.jpg

Photo: IVFL/IAN

Source: http://stratocat.com.ar/fichas-e/1990/MCM-19901221.htm

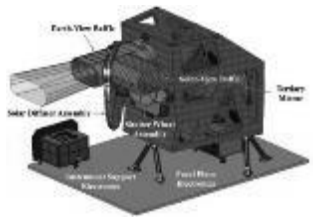


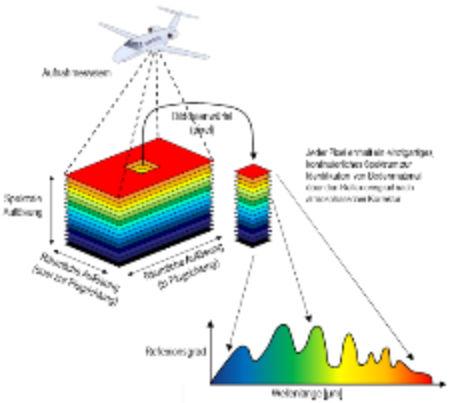
Source: https://www.nextnature.net/2013/09/animals-mistaken-for-spies/

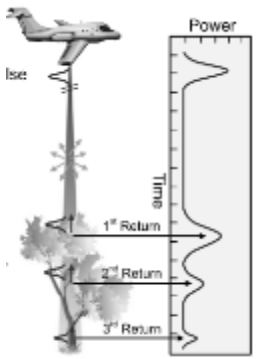
Sensors

Sensors are distinguished by the inner geometry, as well as the geometric, spectral and radiometric resolution. (Note: the temporal resolution is defined by the platform)

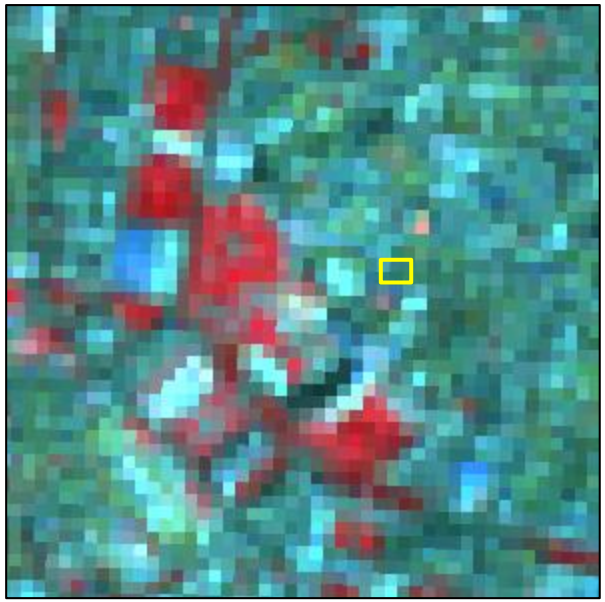
- Cartographic camera *(basically a normal camera)*
- Airborne Laserscanner (ALS) *(used for elevation models)*
- Multispectral-Scanner *(more than 3 channels)*
- Hyperspectralscanner *(a lot more than 3 channels in fine resolution)*
- Thermalscanner *(temperature)*
- Radar *(also for elevation models)*







Spatial Resolution



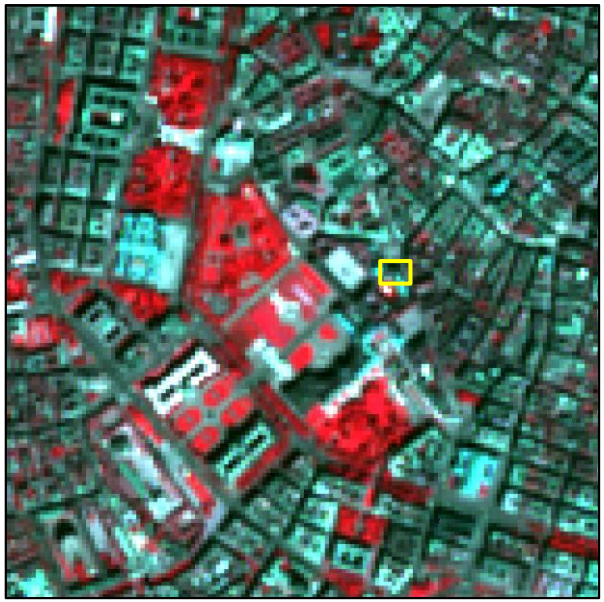
Satellite Image Landsat 8

Multispectral sensor

Spatial resolution: 30 m

shown channels: NIR, R, B

Acquisition date: 2015



Satellite Image Sentinel-2

Multispectral sensor

Spatial resolution: 10 m

shown channels: NIR, R, B

Acquisition date: 2015

Source: ViennaGIS

Orthophoto

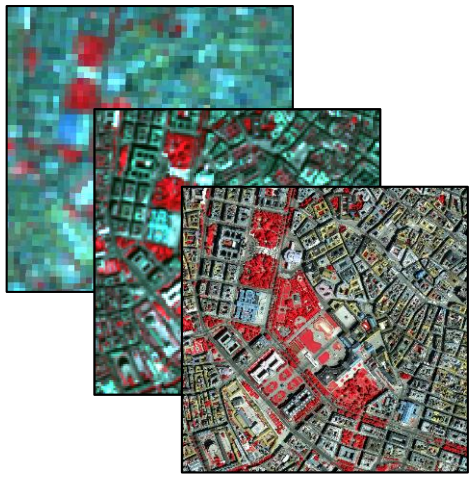
Cartographic Camera

Spatial resolution: 15 cm

shown channels: NIR, R, B

Acquisition date: 2015

Exercise 1: Spatial Resolution

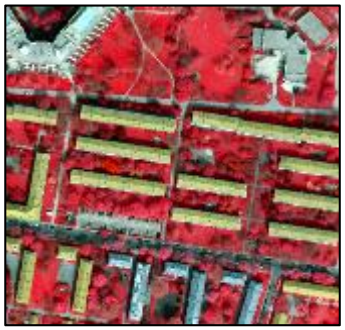


What to do?

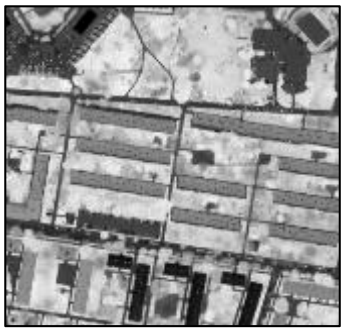
1. Open QGIS.
2. Load all „Exercise 1“-datasets from Vienna (drag&drop) as geo-referenced layers.
3. Group them by selecting and right-click „group“ → Exercise 1
4. Zoom in & out, pan around and get comfortable with the software.
5. Activate/Deactivate layers to look on other layers.
6. Find out the differences between the images (spatial resolution) and comment on them.

Spectral Resolution

R G B



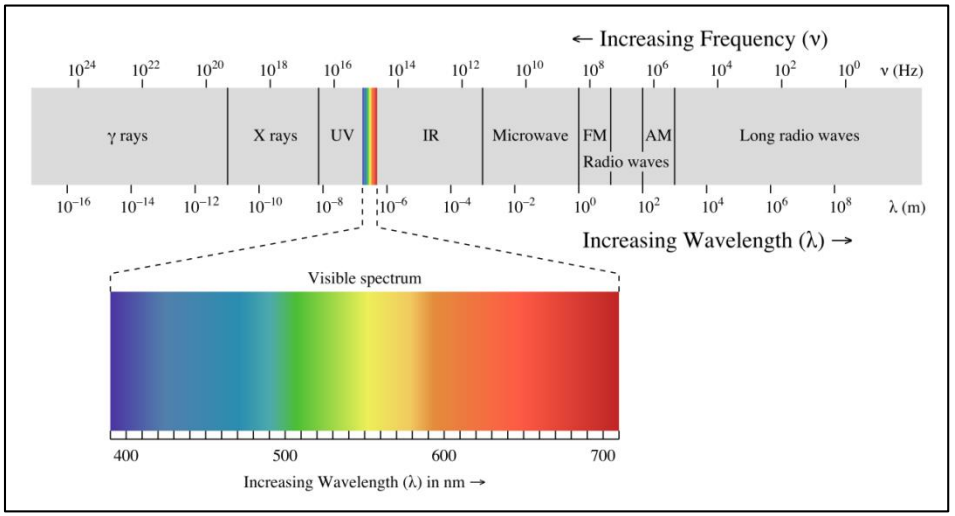
NIR R G



Source: ViennaGIS

$$NDVI = \frac{NIR - R}{NIR + R}$$

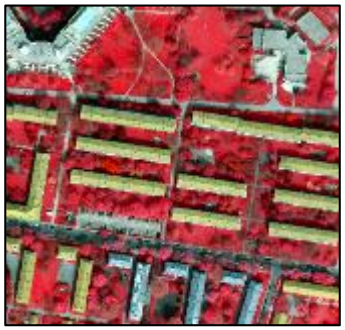
Normalized Difference Vegetation Index



Source: https://thebodyscientific.files.wordpress.com/2014/01/spectrum.png

Exercise 2: Spectral Resolution

R G B



NIR R G

Source: ViennaGIS

What to do?

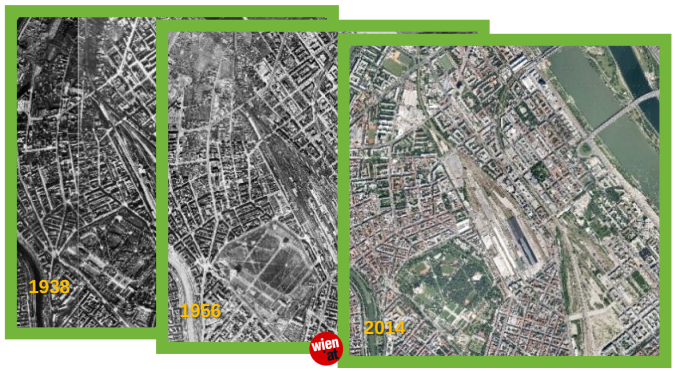
1. Open QGIS.
2. Load both „Exercise 2“-high-resolution orthophotos from Vienna (drag&drop) as geo-referenced layers.
3. Group them by selecting and right-click „group“ → Exercise 2
4. Zoom in & out, pan around and get comfortable with the software.
5. Activate/Deactivate the upper layer.
6. Open the layer properties of each layer to find out more details
7. Find out the differences between the images and comment on them. What is easier to distinguish? What about vegetation types?

Temporal Resolution

- **Satellites**
  - Geostationary satellites → high temporal resolution, but only limited area
  - orbiting satellites → from days to weeks
  - oldest data from ~1970s

Source: Sentinel-2

- **Orthophotos**
  - on demand
  - in Austria: countrywide flights every 3 years
  - oldest (available) data (in Austria) from 1938 → varying



Source: ViennaGIS

- **UAV**
  - on demand → very high temporal resolution possible

Source: own illustration

Exercise 3: Temporal Resolution

Source: ViennaGIS

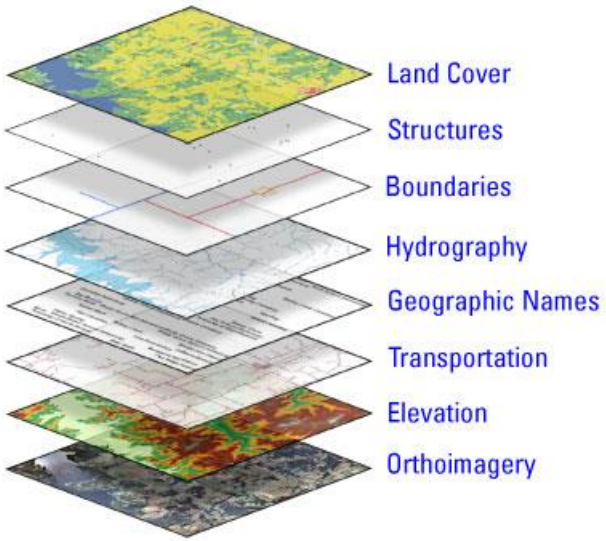
What to do?

1. Open QGIS.
2. Load all „Exercise 3“-multi-temporal orthophotos from Vienna (drag&drop) as geo-referenced layers.
3. Group them by selecting and right-click „group“ → Exercise 3
4. Activate/Deactivate the upper layer.
5. Find out the differences between the images and comment on them. What changed? What can you see?

Image as a map-like representation of the land surface

Aerial and satellite images → need for geometric correction:

- To compare satellite images of several different sensors;
- To locate geo-referenced (GPS) ground data (training for classification, ground reflectance, etc…) from field survey;
- Mosaics two or more images;
- Creation of a GIS data set;
- …



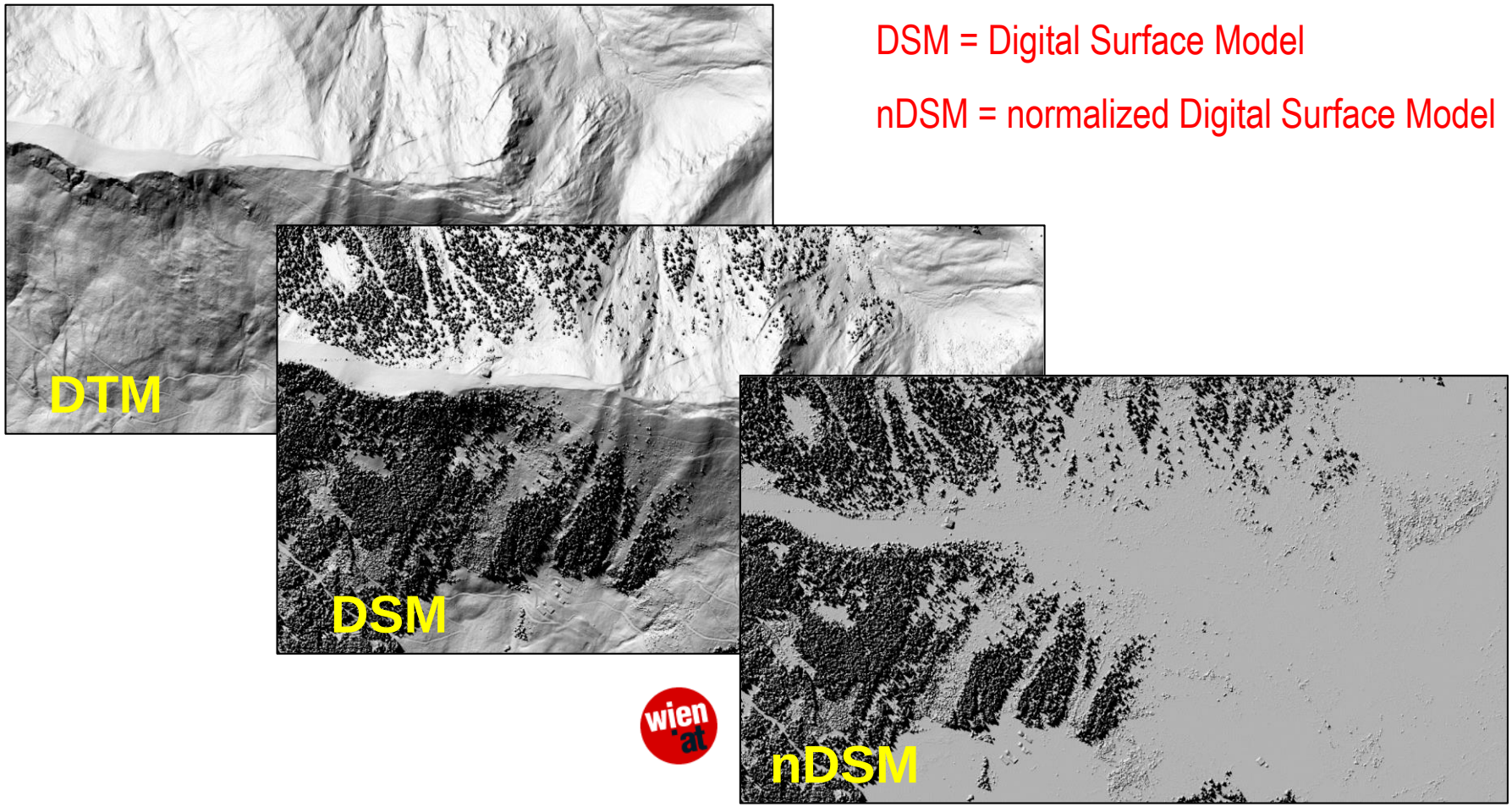
Source: https://commons.wikimedia.org/wiki/File:USGS_The_National_Map.jpg

Airborne Laserscan data

DTM = Digital Terrain Model

DSM = Digital Surface Model

nDSM = normalized Digital Surface Model



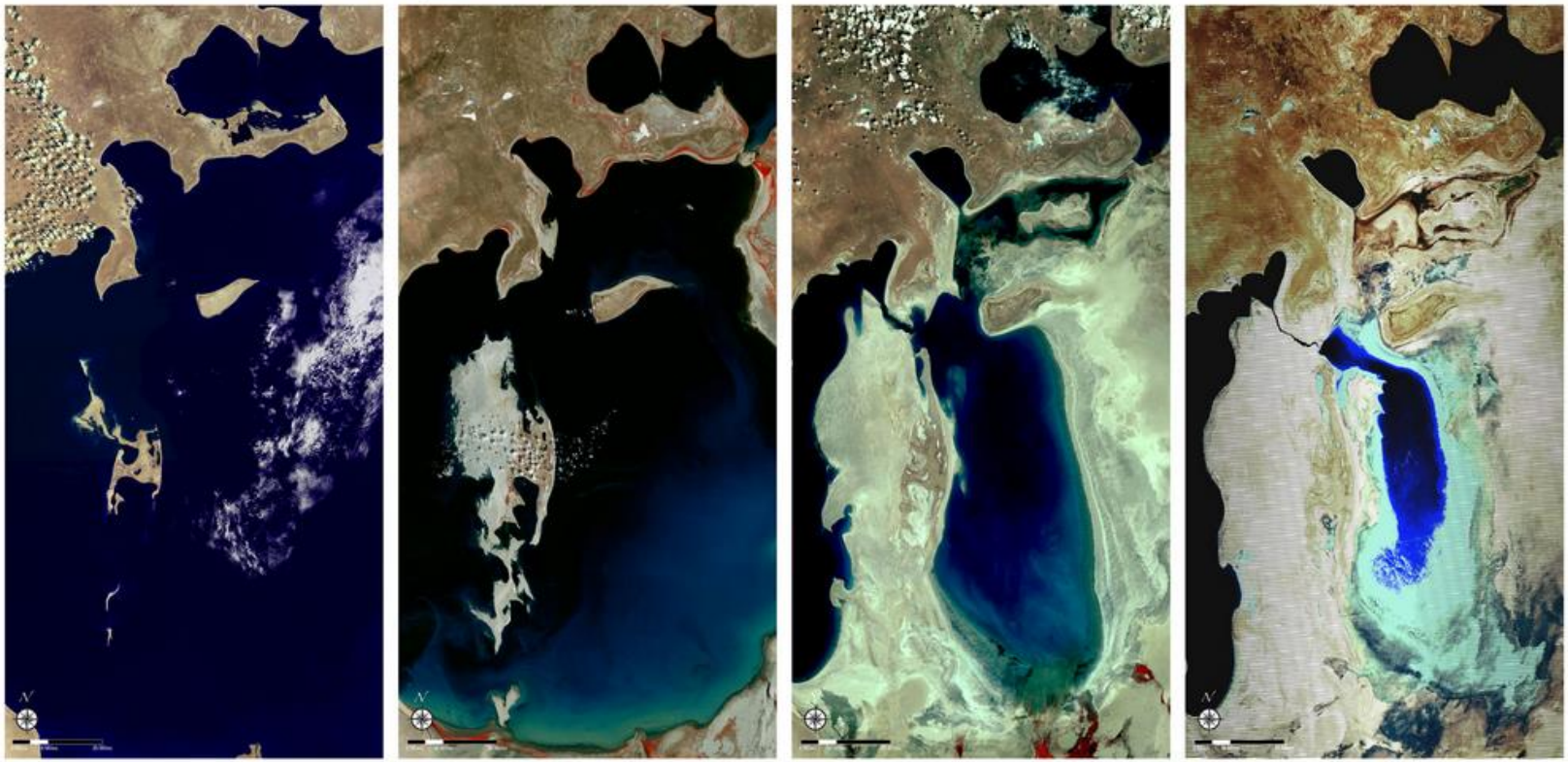
Source: ViennaGIS

Advantages of Geodata from Remote Sensing

- documentation *(images are persistent documents)*
- continuous information instead of discrete
- comparability *(time series)*
- high degree of automatisation possible when doing analyses
- retrospective analyses possible *(historic geodata)*

Change Detection: Landsat Time Series

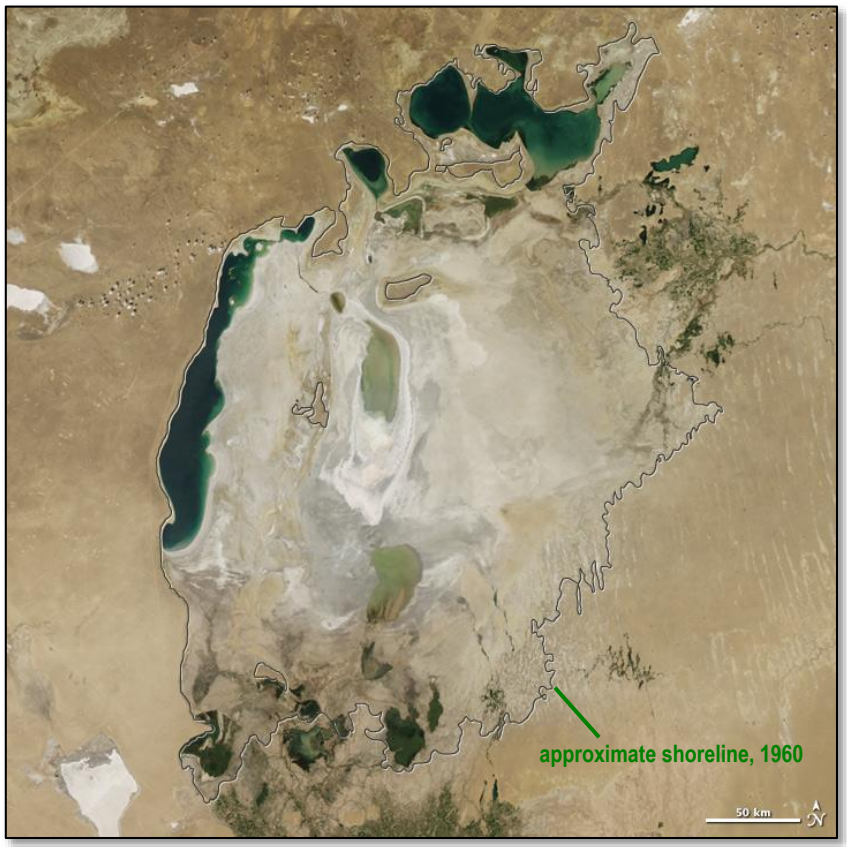
Lake Aral: Time Series



Source: https://www.usgs.gov/

Change Detection: Landsat Time Series

August 13, 2015



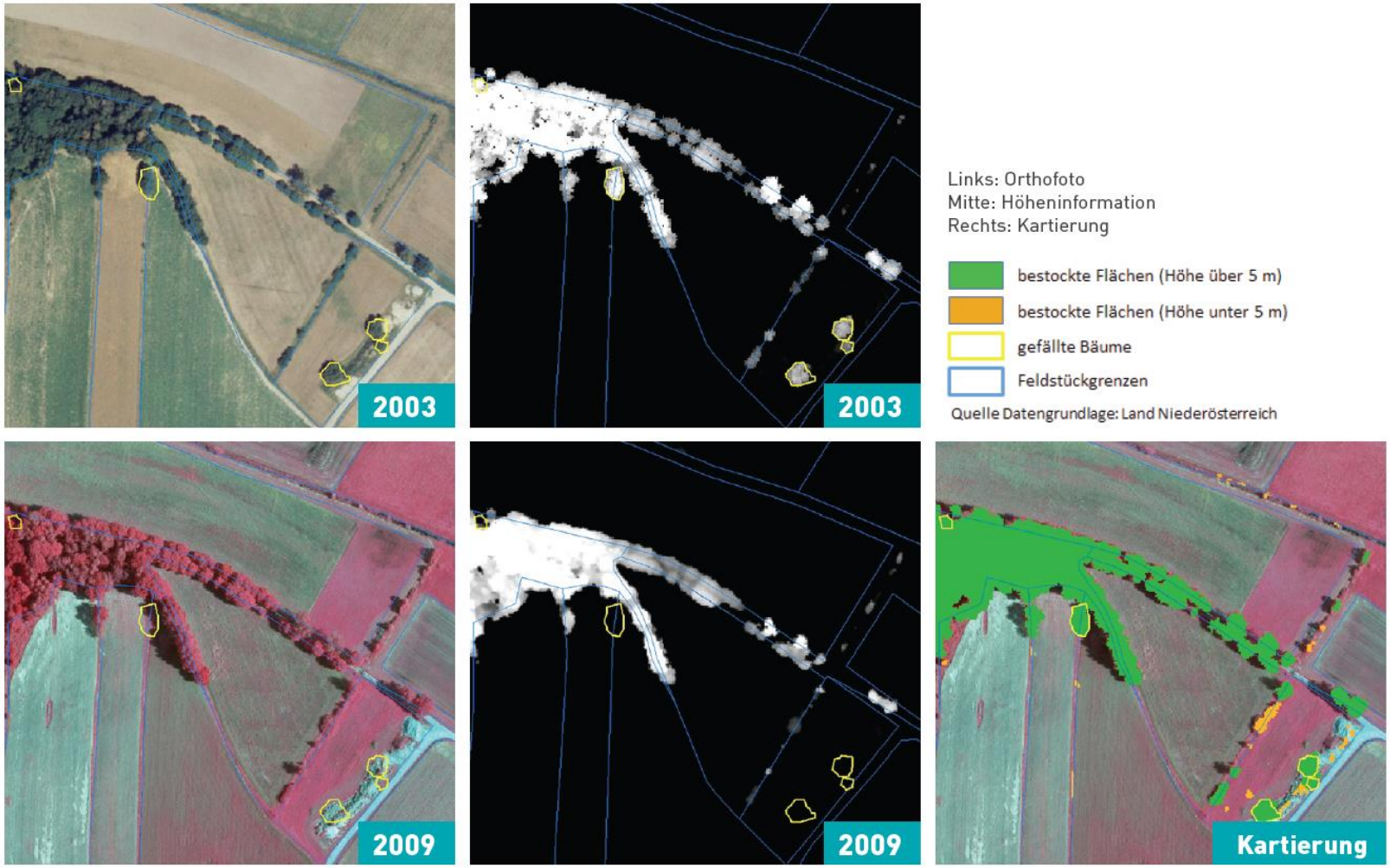
http://scienceblogs.de/astrodicticum-simplex/wp-content/blogs.dir/28/files/2012/09/i-8d5fce9e46cce47a9d26e001ac412c54-aralsea_tmo_2000238-thumb-500x500-32160.jpg

http://earthobservatory.nasa.gov/Features/WorldOfChange/aral_sea.php

Change Detection: Urban & Forest

Source: http://www.landinformationsystem.at/

Combination of Images & Height information



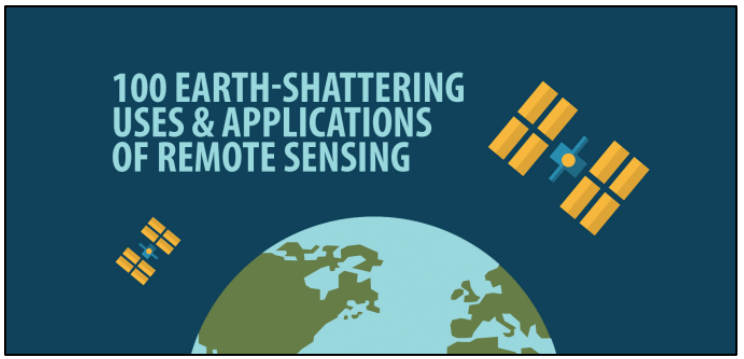
Source: http://www.landinformationsystem.at/

Uses and Applications of Remote Sensing

1. Determining soil moisture content using active and passive sensors from space
2. Mapping with laser precision using Light Detection and Ranging technology
7. Charging higher insurance premiums in flood-prone areas using radar
10. Detecting oil spills for marine life and environmental preservation
11. Counting polar bears to ensure sustainable population levels
13. Identifying forest stands and tallying their area to estimate forest supplies
17. Delineating and assessing the health of riparian zones to conserve lakes and rivers
18. Estimating surface elevation with the Shuttle Radar Topography Mission
20. Watching algae grow as an indicator of environmental health
22. Detecting land cover/use types for decision making
24. Mapping soil types for agriculture planning
34. Studying glacier melts and effects on sea levels
39. Quantifying crop conditions with Normalized Difference Vegetation Index (NDVI)

...

And MANY more!!!



http://gisgeography.com/100-earth-remote-sensing-applications-uses/

Remote Sensing in Sustainable Land Management

- Only 37 % of Austria‘s surface can be used for settlements (Tirol: 12 %)
- many multifaceted, competing use demands
- Management necessary → comprehensive data needed → Remote Sensing!

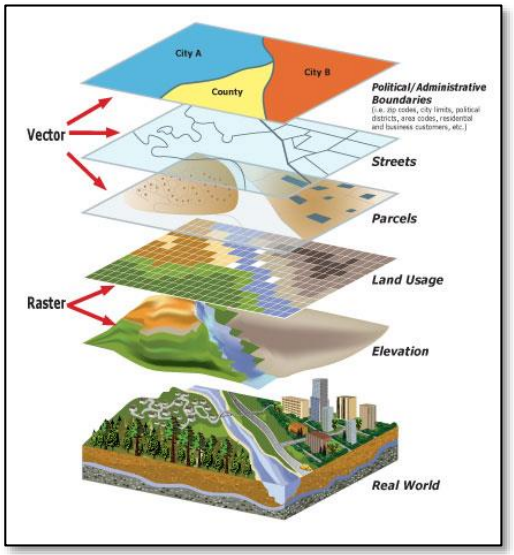
Source: www.alpenrhein.net

Remote Sensing is used for homogenious, comprehensive, operational land monitoring and documentation!

2. GEOGRAPHIC INFORMATION SYSTEMS (GIS)

What is a Geographic Information System ?

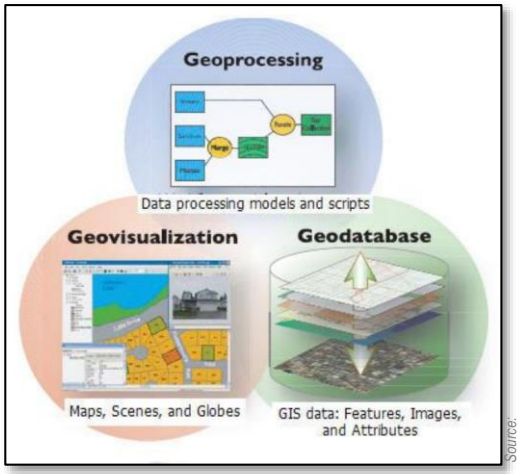
A GIS is a **set of tools** (hardware & software) for **managing, analyzing, communicating** spatial data (vector or raster layers) and associated information (databases) from the real world.



Source: http://guides.sfsq.georgetown.edu/gis

It consists of **3 components**:

- **Geodatabase:** Organization and referencing of geodata
- **Visualisation:** Determination and cartographic display
- **Analysis tools:** Scripts and models for geostatistic analysis and assessment



Source: https://www.lzg.nrw.de/_media/pdf/service/veranstaltungen/121115_zfb/buck_geoinformationssysteme_und_ihre_potentiale_15-11-2012_duesseldorf.pdf

GIS-Software

- ArcGIS (10.3) ESRI 

- Open Source GIS (Quantum GIS) 
- Web-Map-Services
  - Google Maps/ Google Earth / Bing Maps   

  - OpenStreetMap Project 
- Mobile GIS-Software (ArcMobile, OpenStreetMap)
- …

Introduction to Quantum GIS (QGIS)

Open-source Geographic Information System (Python)

GUI with build in toolboxes (Orfeo, GDAL, GRASS, SAGA,...)

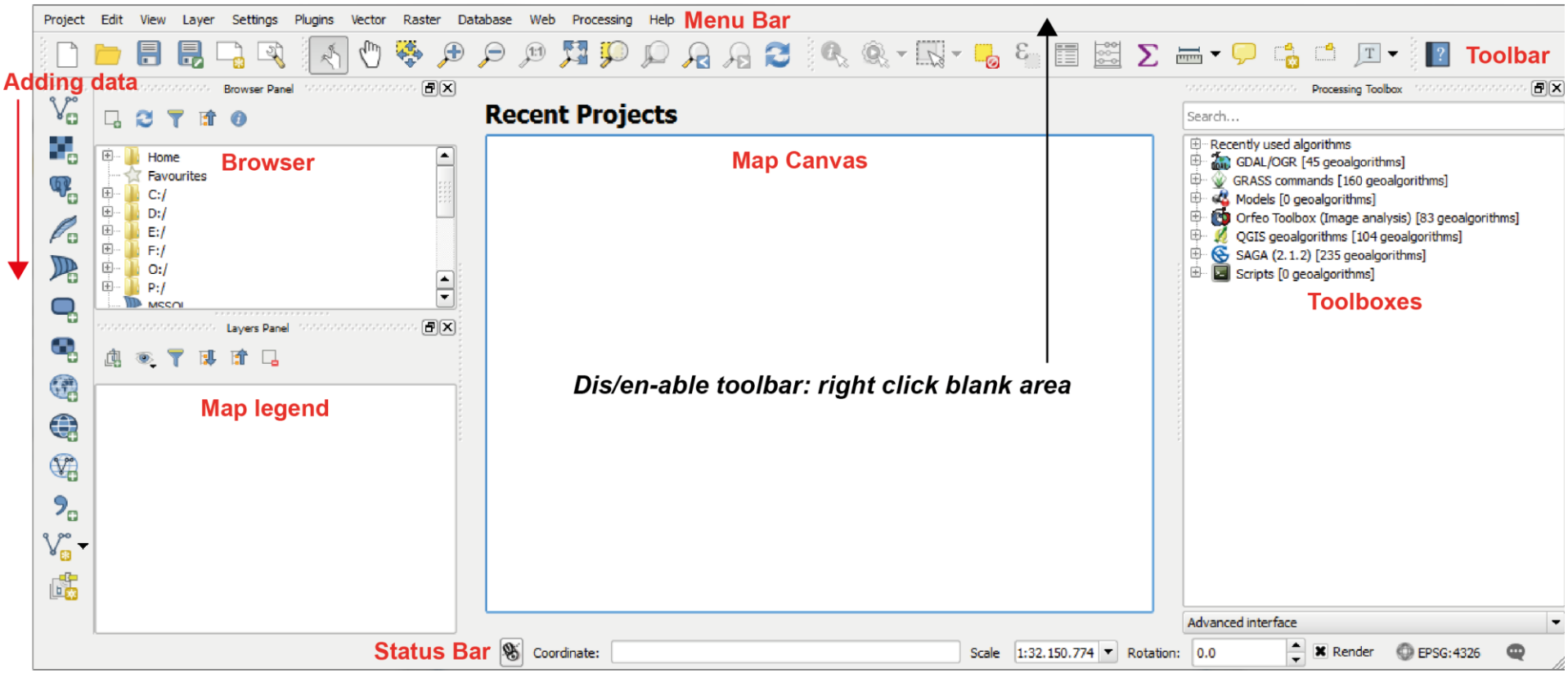
Input data:

- Raster (tif, img,jpg...)
- Vector (shp, csv, dxf, kml,...)
- …

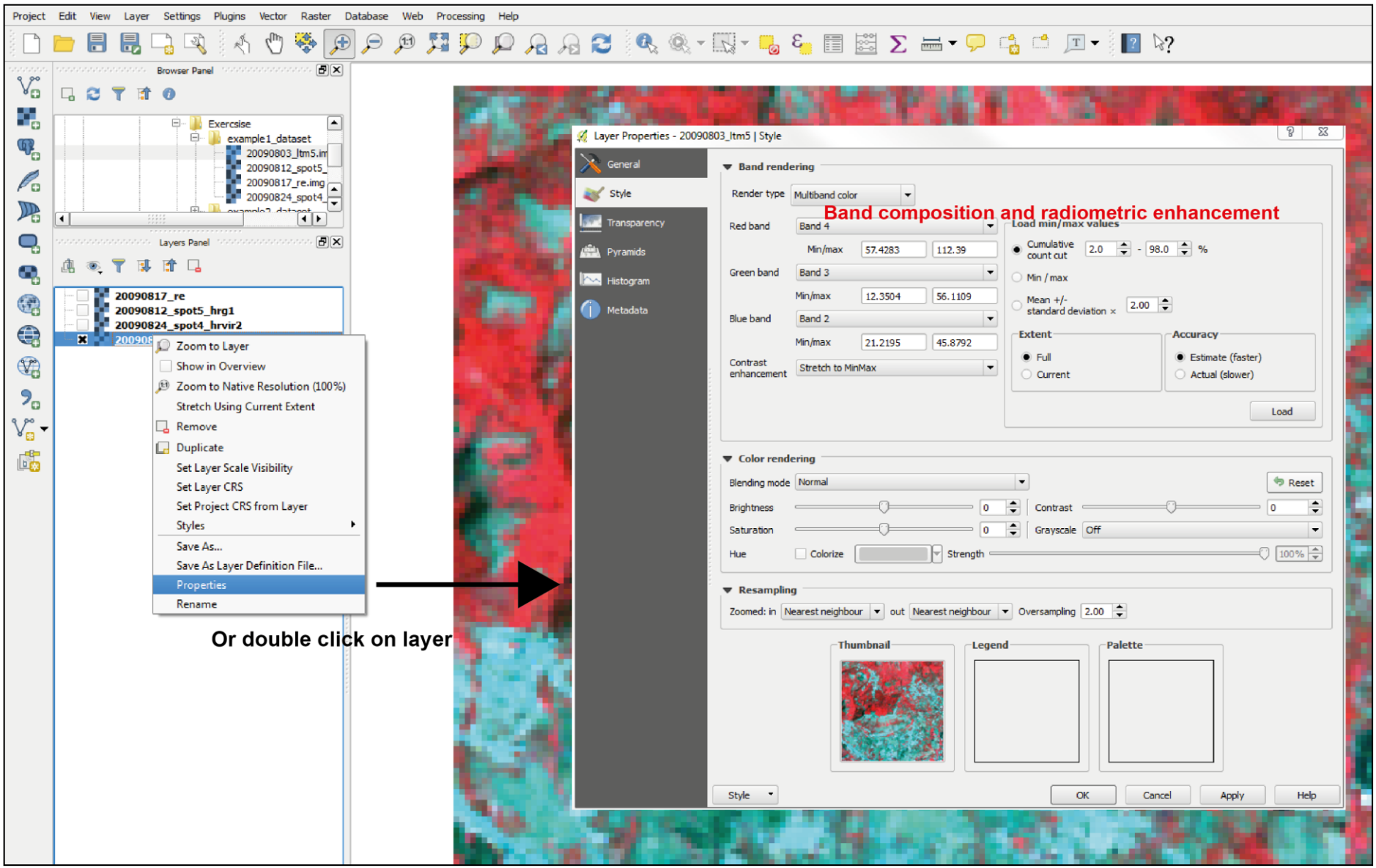
Output:

- Maps (pdf, jpg)
- Databases
- Spreadsheets
- Raster or vector data

QGIS interface



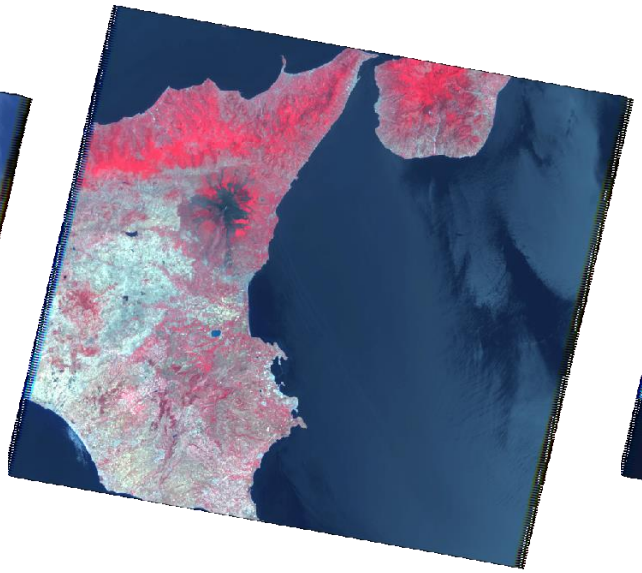
Layer properties



Band combination

Right click on layer → Properties → Style → Band rendering

TM True color (3,2,1)

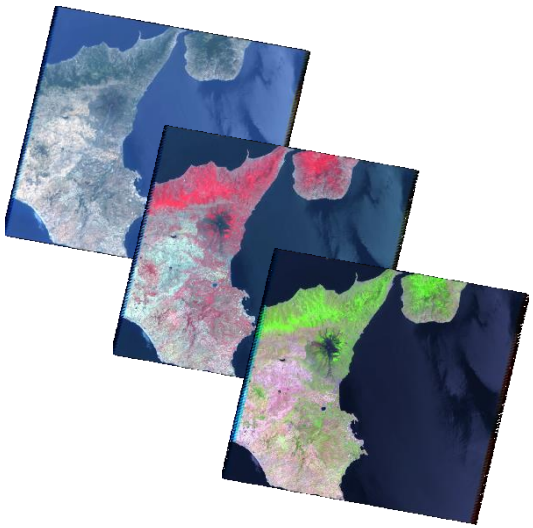


TM False color IR (4,3,2)

TM False Natural color (5,4,3)

Source: http://earthexplorer.usgs.gov/

Exercise 4: Band combinations of Landsat

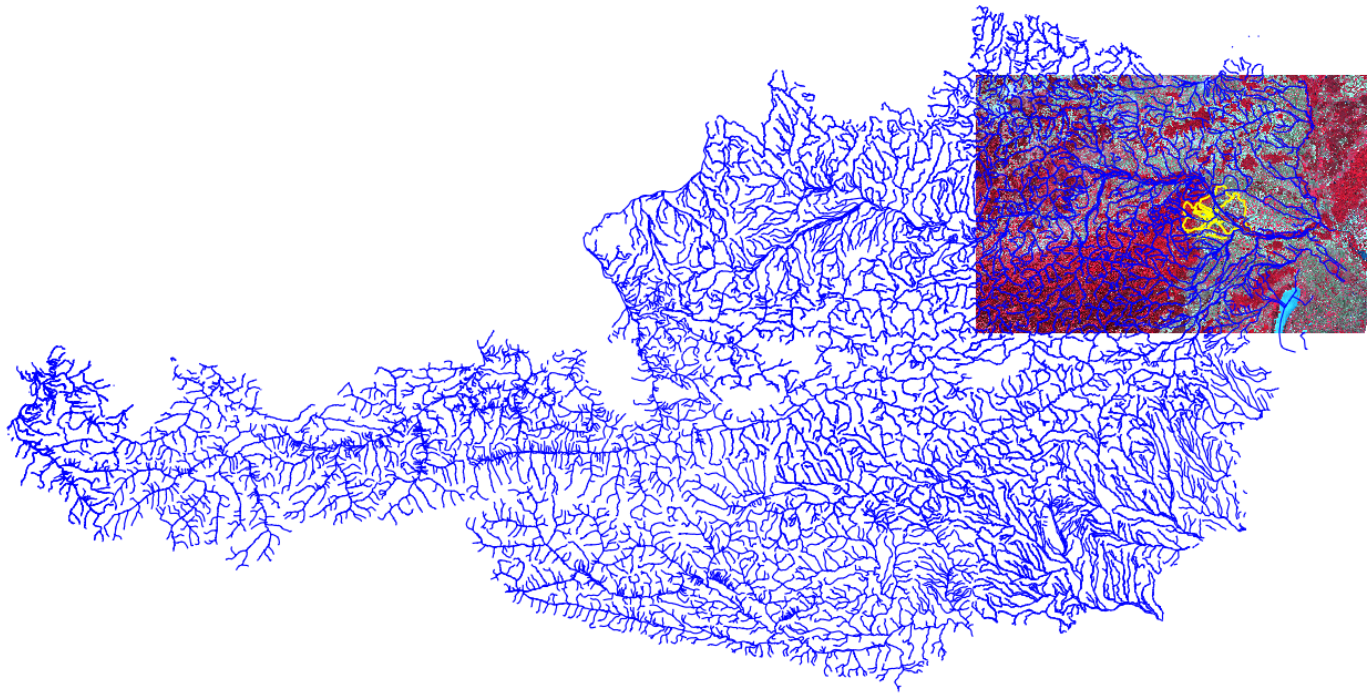


Source: http://earthexplorer.usgs.gov/

What to do?

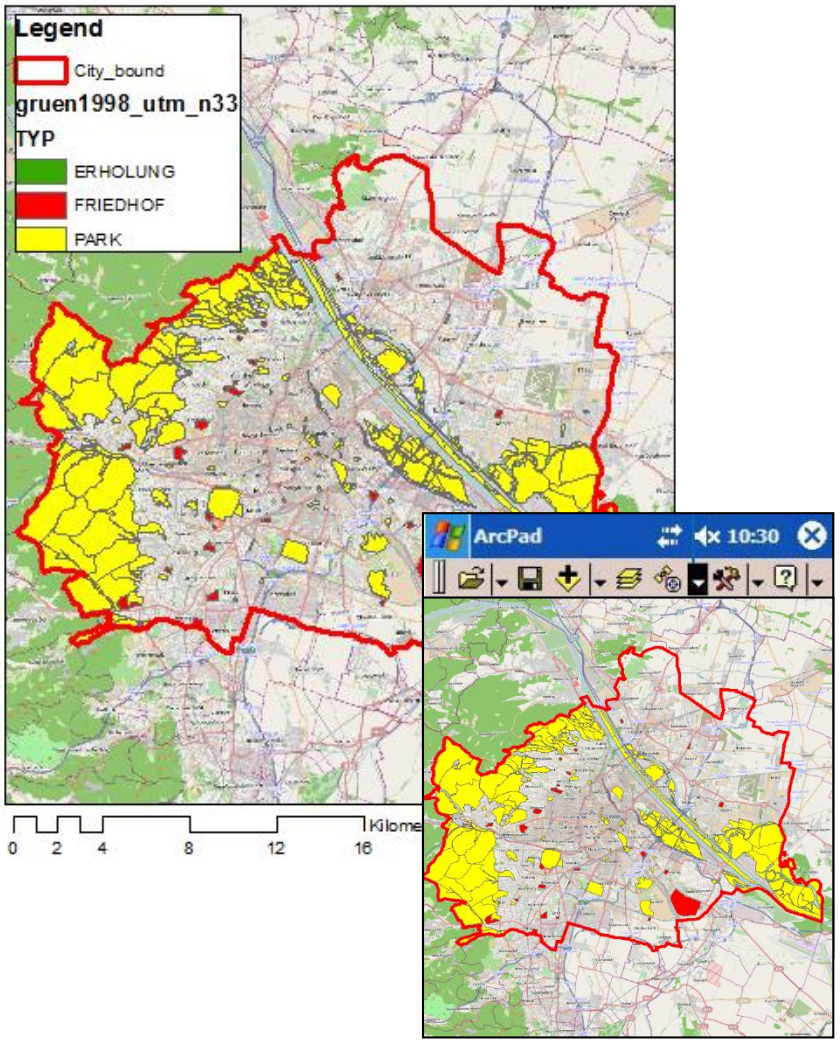
1. Open QGIS.
2. Load all „Exercise 4“-datasets from Vienna (drag&drop) as geo-referenced layers.
3. Group them by selecting and right-click „group“ → Exercise 4
4. Right click on layer → Properties → Style → Band rendering
5. Try different combinations (3-2-1, 4-3-2, 5-4-3)
6. Find out the differences between the images and comment on them.

EXAMPLE: Vector Data overlay

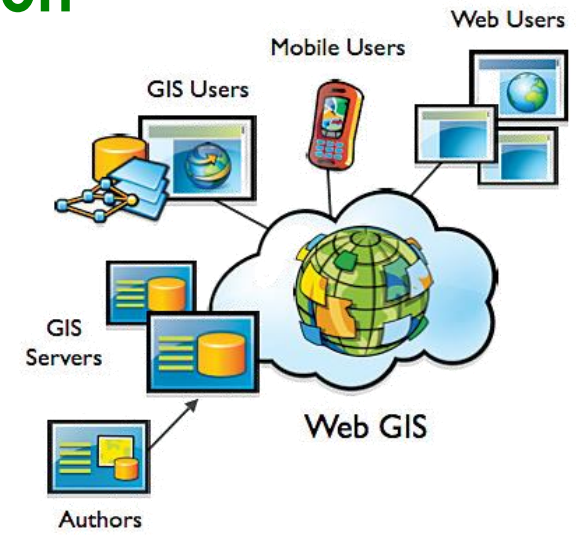


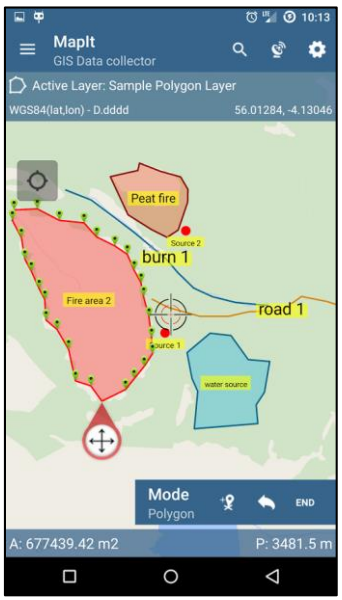
Source: EAA (Environmental Agency Austria)

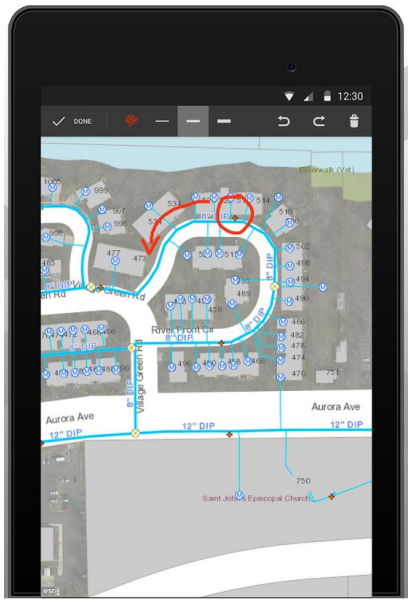
Dissemination and use of information

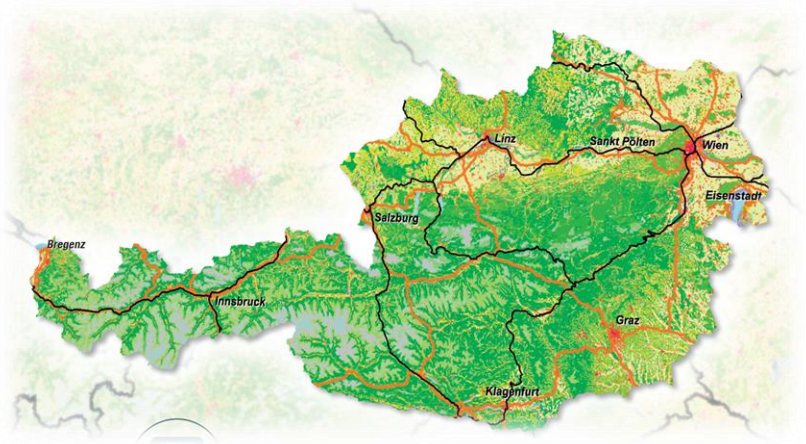


Source: ViennaGIS





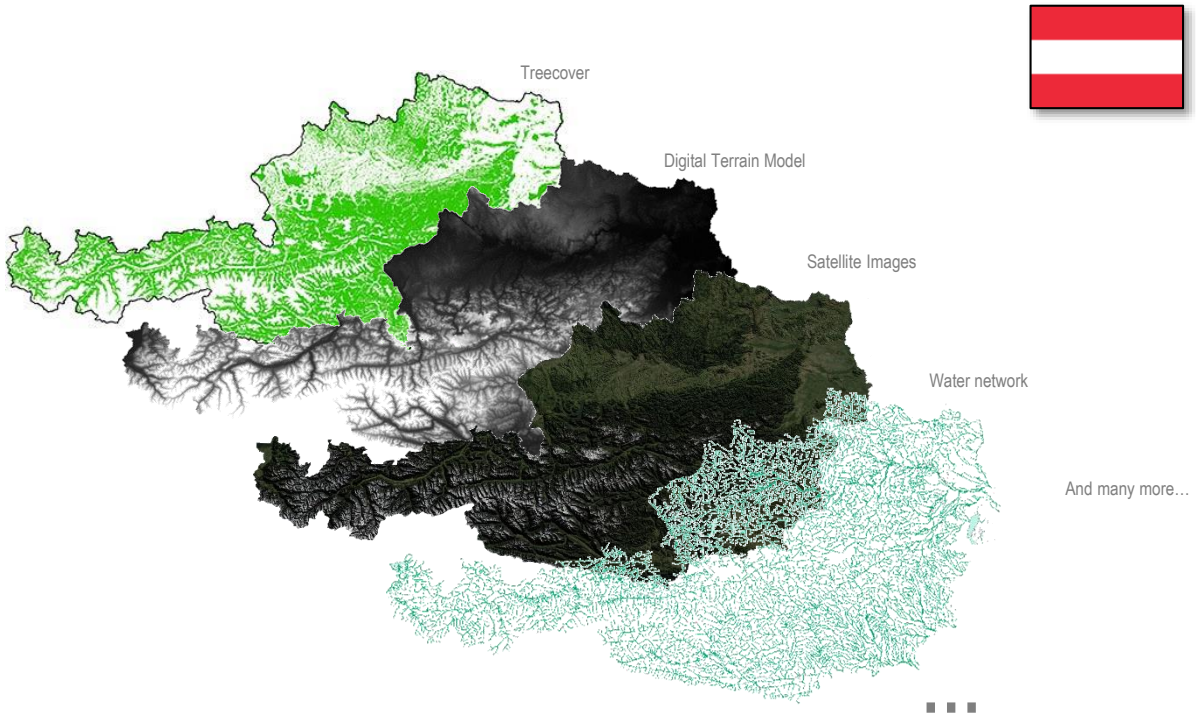




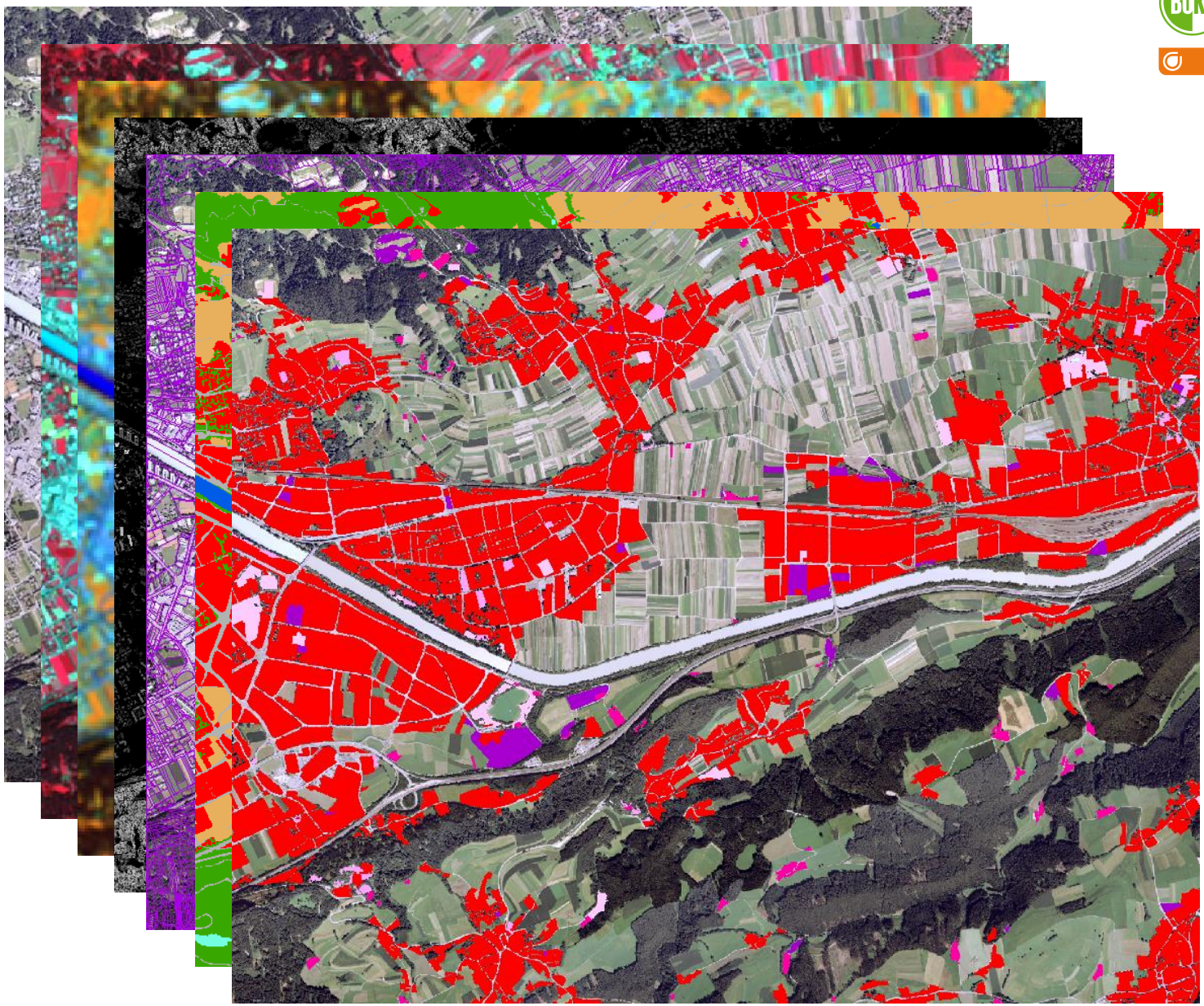
3. NATIONAL SPATIAL INFRASTRUCTURE IN AUSTRIA

Available Datasets in Austria

- Satellite Images
- Orthophotos
- Airborne Laserscan Data
- Cadaster maps
- Hydrological maps
- … and many other datasets!



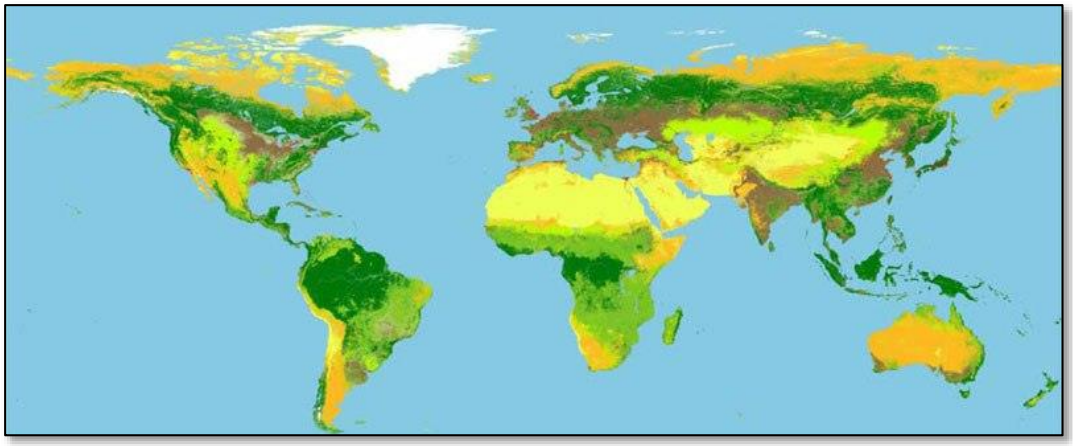
- data.gv.at – open data Austria



Source: http://www.landinformationsystem.at/

Available Geodata in Austria

- Adresses
- Riparian inventar
- Water network (rivers, lakes)
- Digital Terrain Model (10 m) → also 1 m for certain areas
- DKM – Digital Cadaster Map
- ÖK50 (generalized map)
- Street network / GIP
- INVEKOS (field plots)
- Treecover
- ….



4. LAND COVER MAPPING

Land Cover Classification

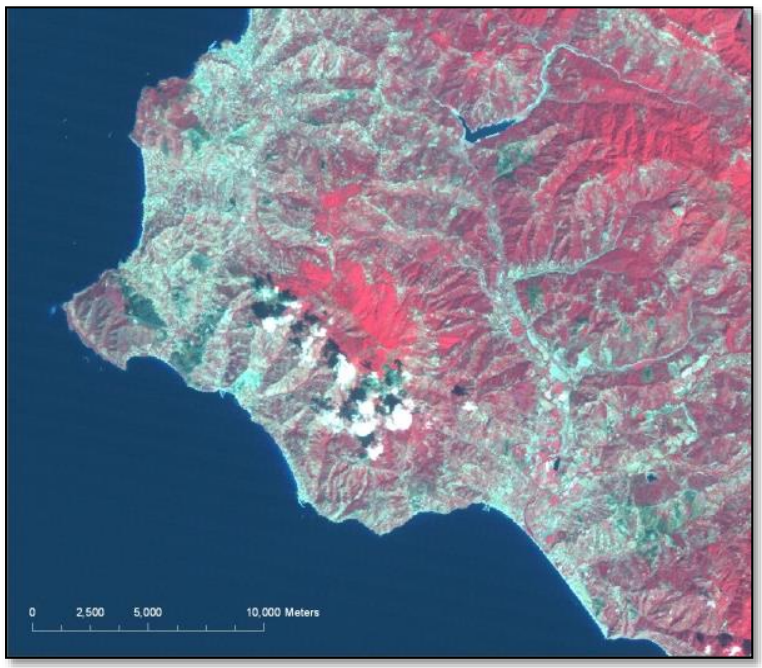
Example of a simplified land cover map (Lans, Tirol, Austria)

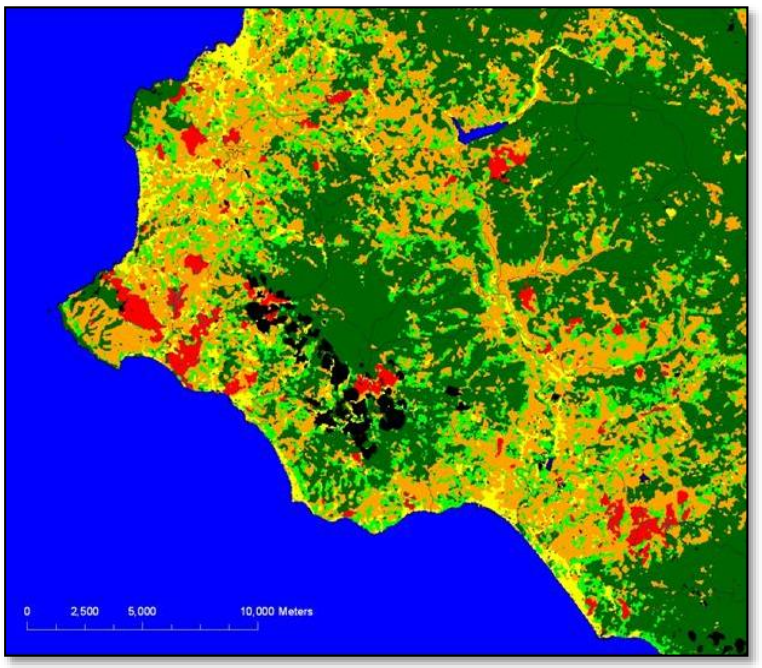
Source: http://www.landinformationsystem.at/

Land Cover Classification

Classification is the process of assigning pixels to categories (organize data into categories) based on their numerical properties (DN, radiance, reflectance, etc…).

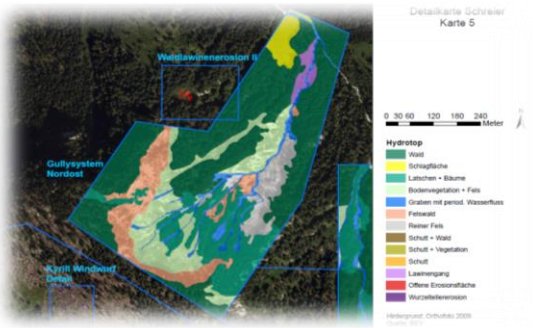
Raster data → **Thematic map**



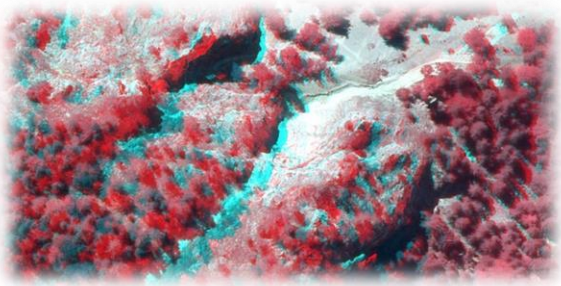


Assessment methods

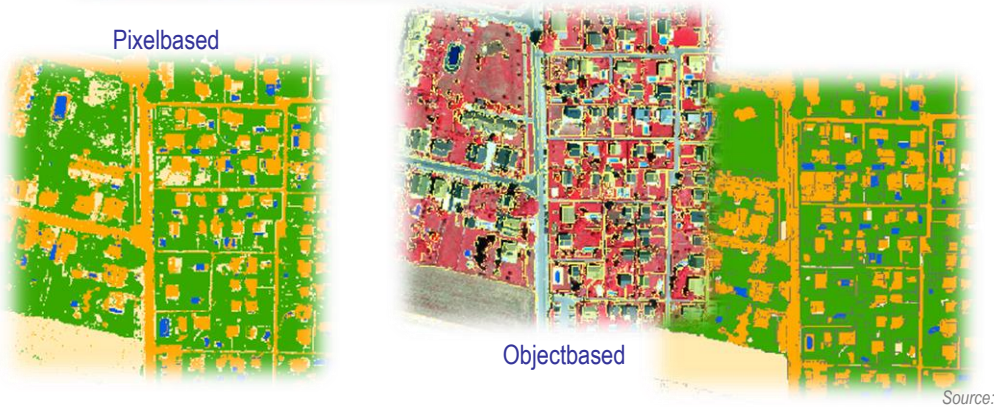
- Visual interpretation and manual segmentation
  (Orthophoto → two-dimensional)



- Stereoscopic assessment
  (Photogrammetry → three-dimensional)



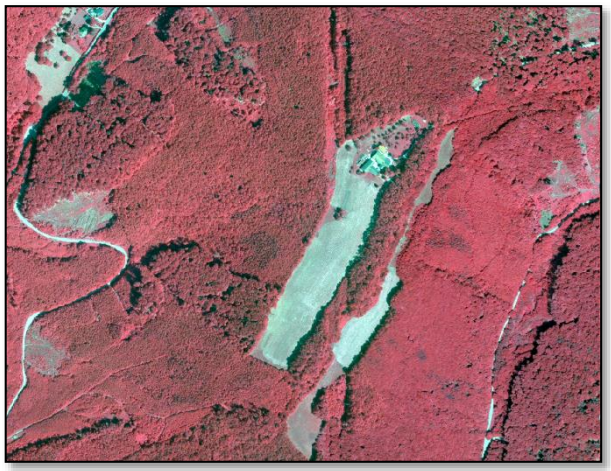
- Automatic methods
  - objectbased classification
  - pixelbased classification



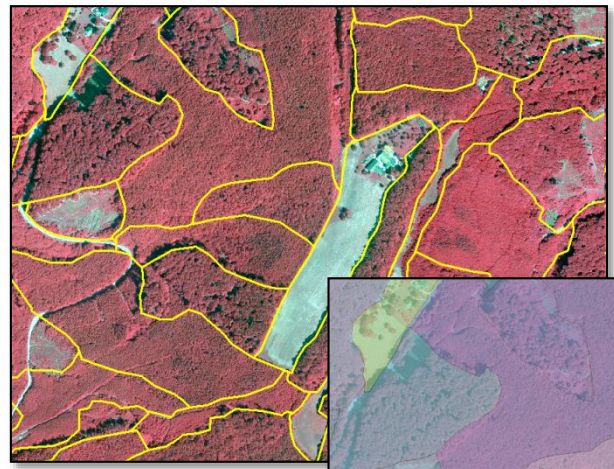
Source: BEV

Manual Assessment

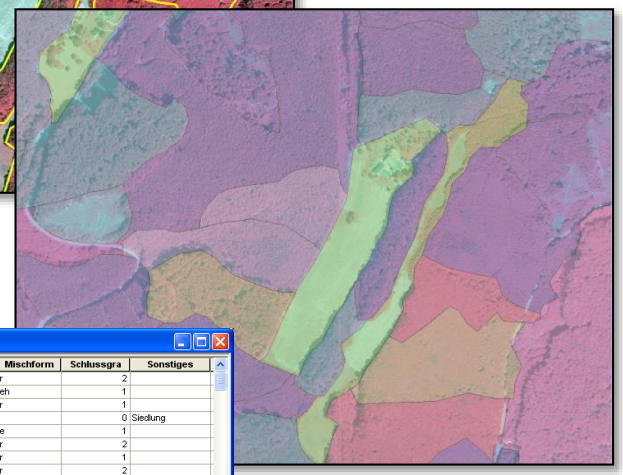
creation of a land cover map



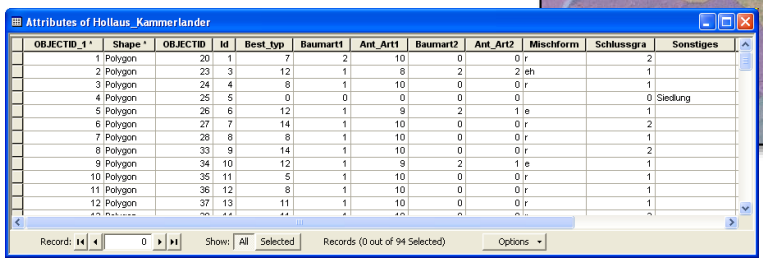
Orthophoto



Mapping



Landcover



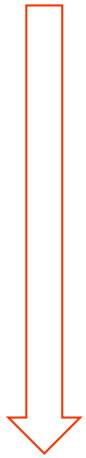
Attribute table

Source: ViennaGIS/own illustration

Needs for Land Cover maps

- Modelling ecosystems interactions (energy, water and carbon flux exchanges), climatology

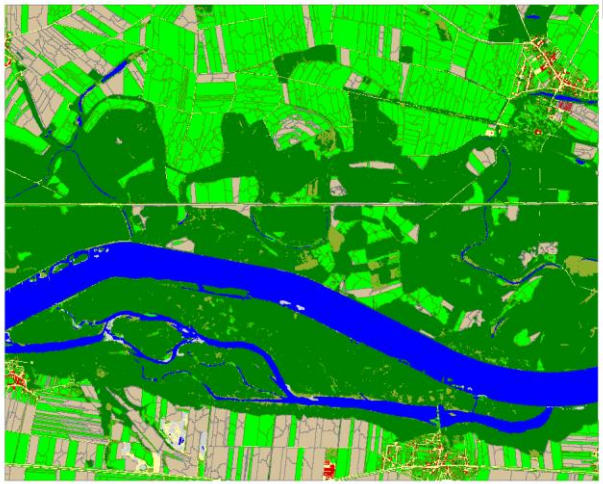
Global scale



- Planning, land change monitoring & policy development:
  - Deforestation;
  - Bio-fuels production;
  - Agriculture;

Regional to local scale

Land Cover & Land Use // Land Information System Austria (LISA)



Land COVER

- buildings
- other sealed surfaces
- bare Soil
- sand
- rock
- water
- snow
- ice
- timber
- shrub
- dwarf shrub
- grass
- reed
- shadow

Land cover is the observed (bio)physical cover on the earth's surface.

Examples: forest, grass, desert, water,...

Land USE

- settlement
- estate
- public park
- sport
- technical infrastructure
- road
- railroad
- airport
- parking
- field
- grassland
- mountain pasture
- special culture
- field wood
- forest
- bare areas
- forest grass
- glacier
- rock
- debris
- alpine grass
- dwarf shrubs
- other natural areas
- running water
- stagnant water

Land use is how people utilize the land (including the socio-economic activities):

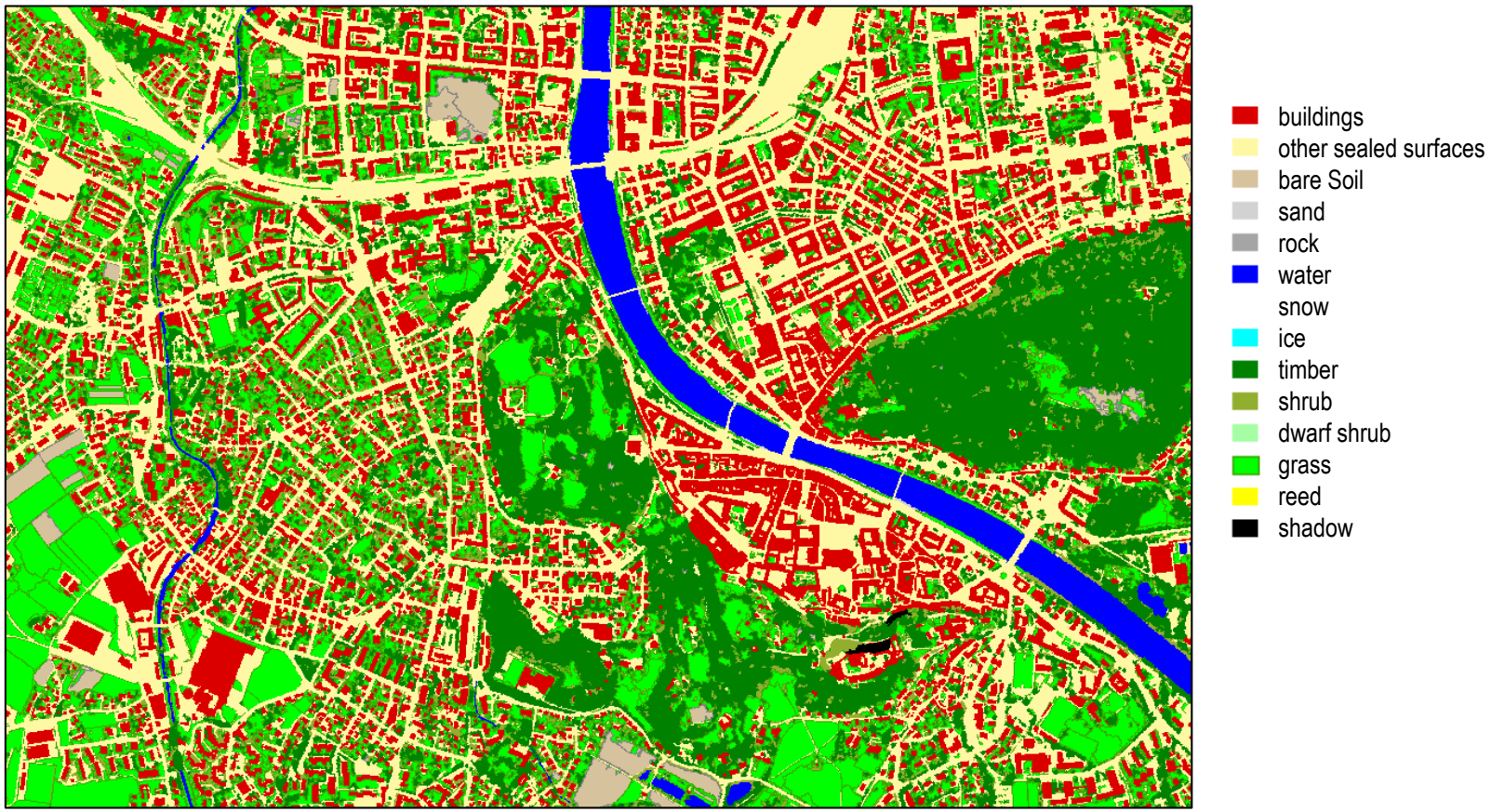
Examples: urban and agricultural land…

Source: http://www.landinformationsystem.at/

What type of features can we use for information extraction?

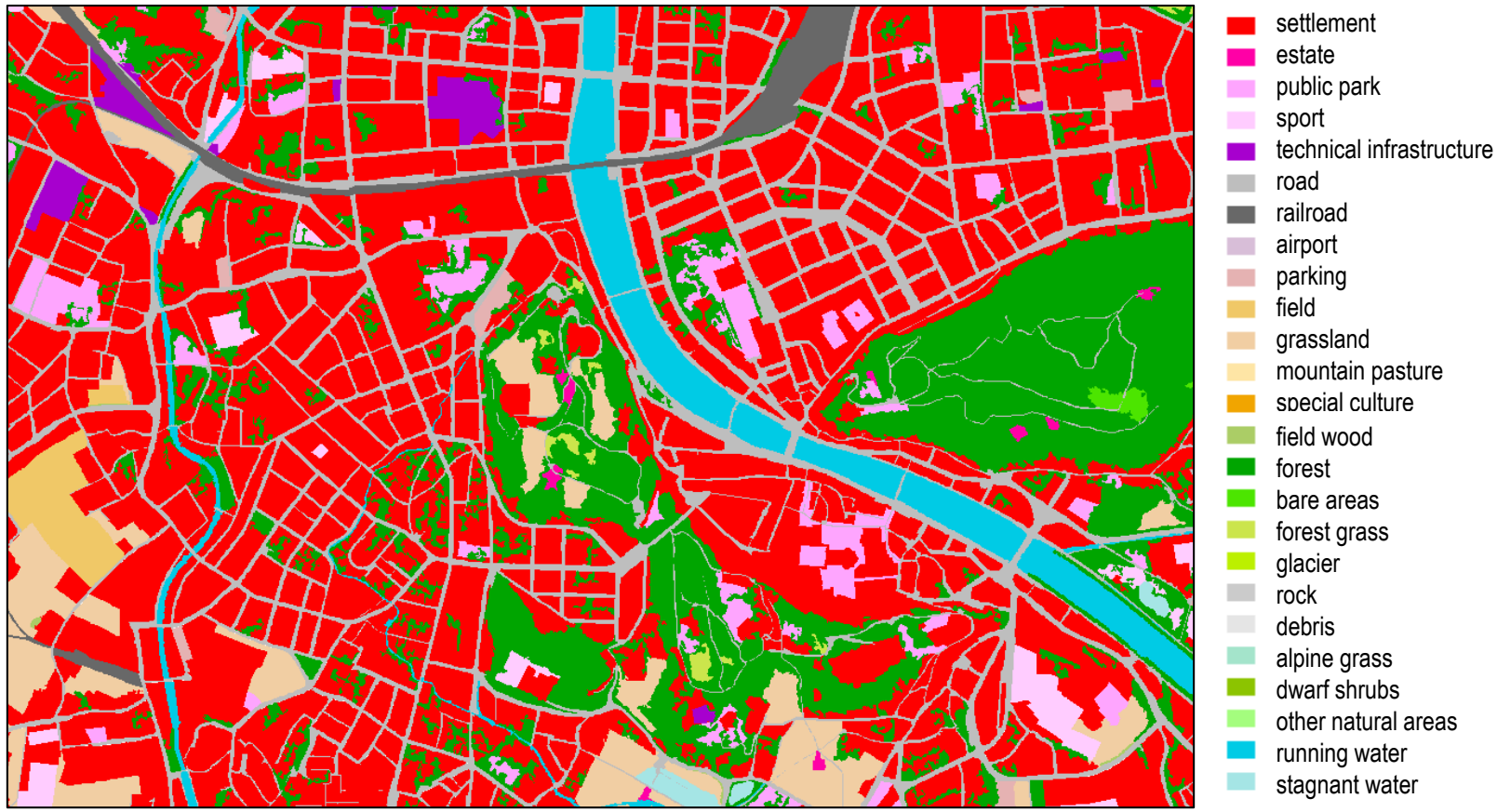
- Spectral information (different spectral bands) from one acquisition;
- Time series (multi-temporal approach);
- Texture and other spatial information;
- Additional information (elevation, slope, soil type, climatology, existing land cover maps, etc.).

Results – Land Cover

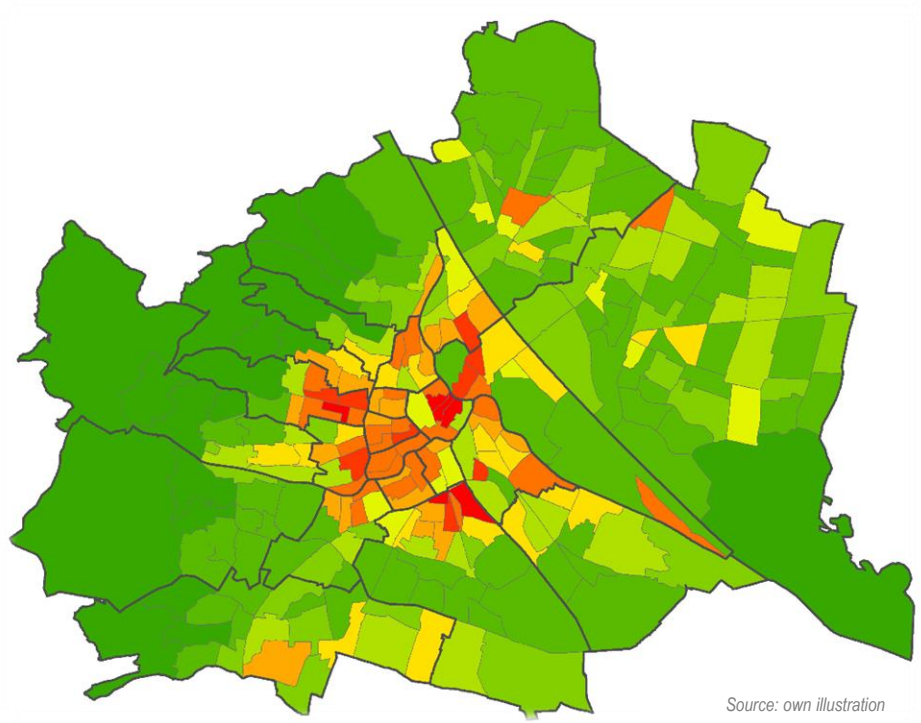


Source: http://www.landinformationsystem.at/

Results – Land Use



Source: http://www.landinformationsystem.at/



Source: own illustration

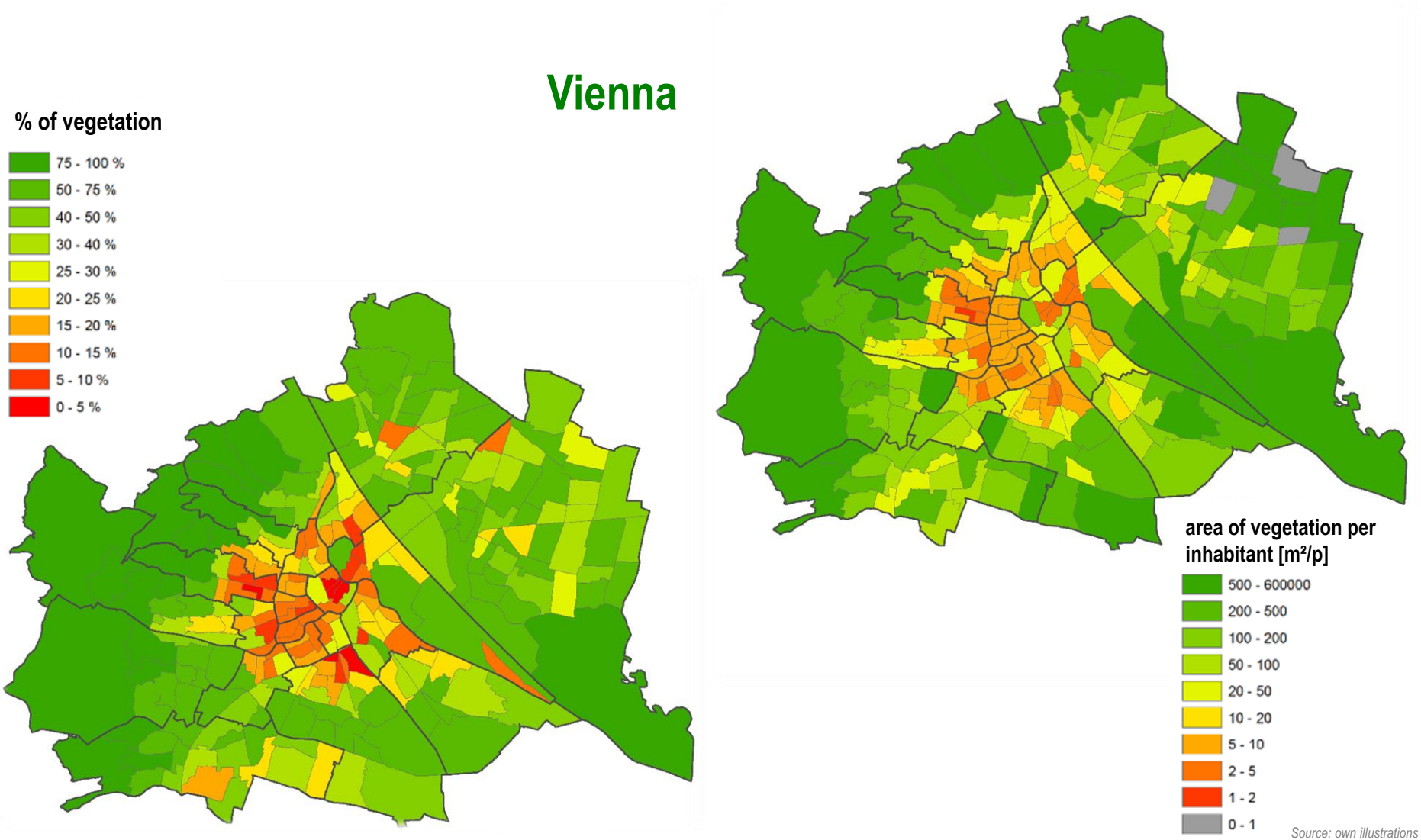
5. INDICATORS

Source:

Lindner G., Mansberger R. (2016): Handlungsziele für Stadtgrün und deren empirische Evidenz (LB 2.3 – Modul Fernerkundung)

Indicators calculated from LC classification

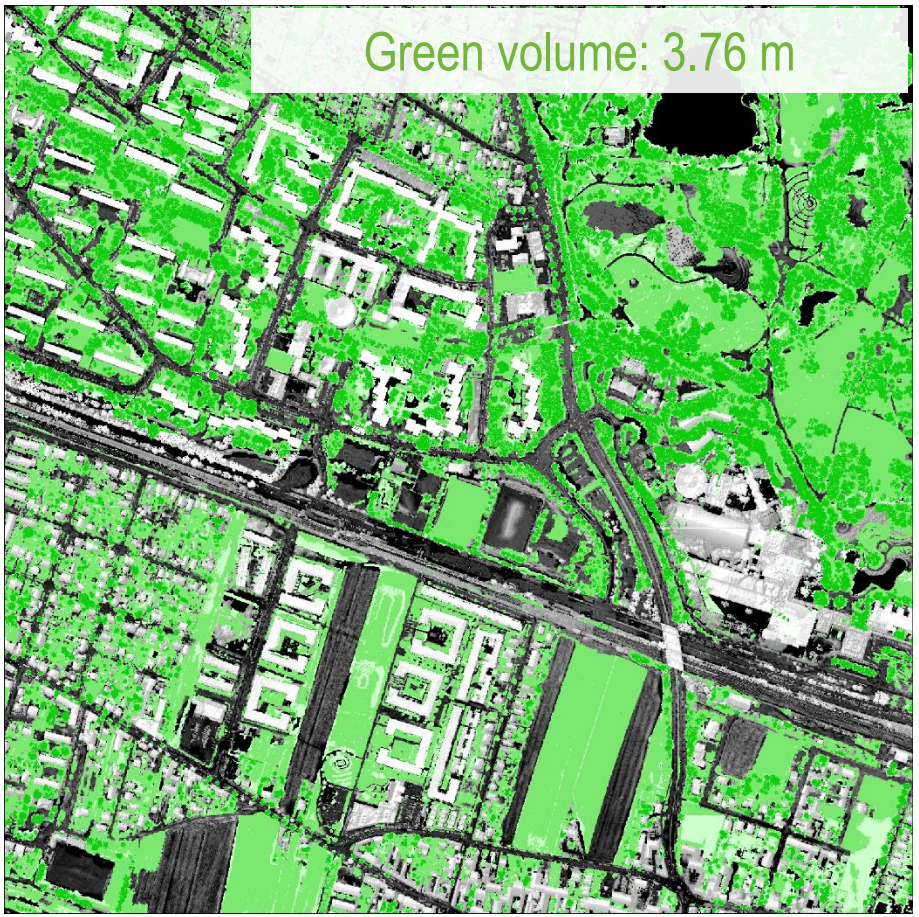
Vienna



Source: own illustrations

Indicators calculated from LC classification

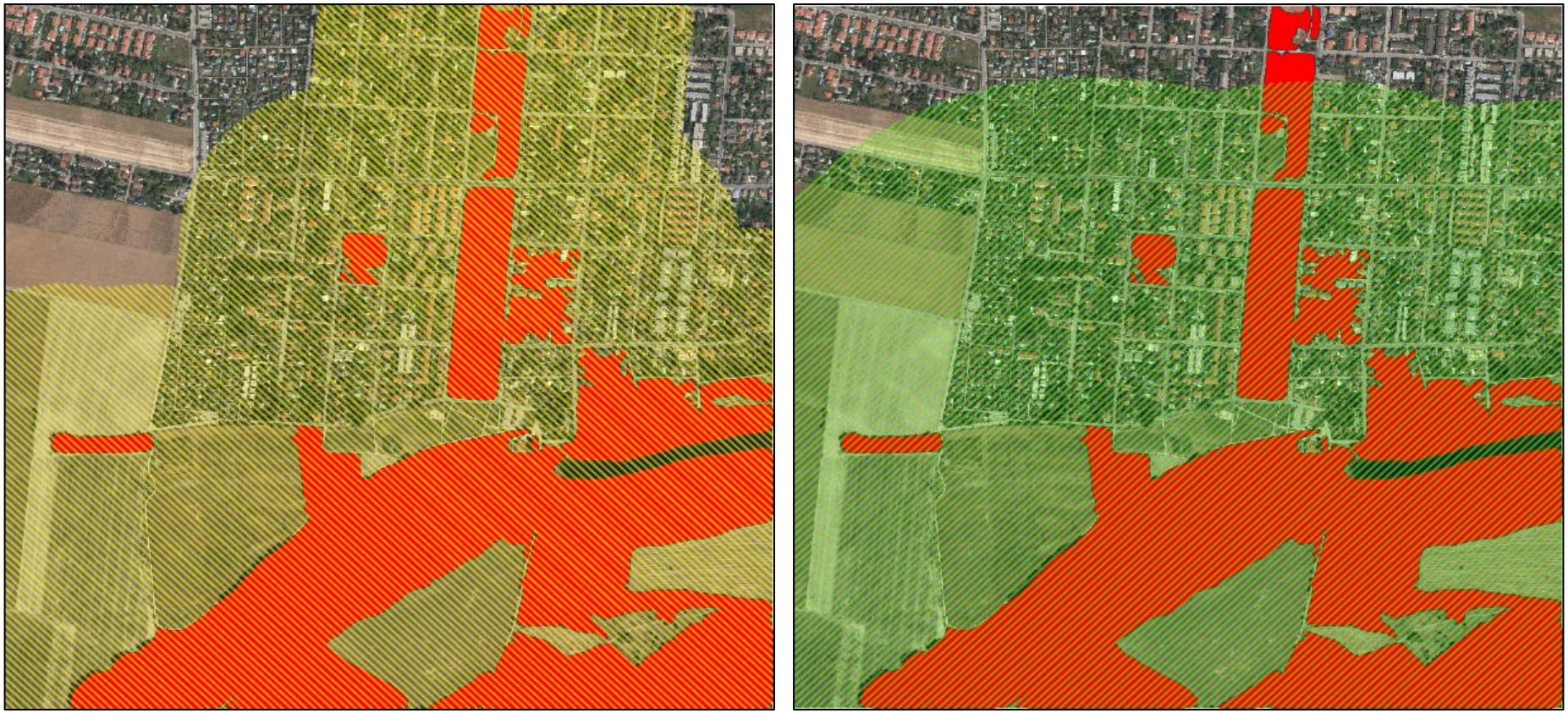
Green areas



Green areas in 3 different heights

Source: own illustration / ViennaGIS

Indicators calculated from LC classification



Red: Green areas > 0.5 ha
Yellow: Buffer of 300 m from every green area between 0.5 ha and 10 ha;
Green: Buffer of 700 m from every green area > 10 ha

Source: own illustration / ViennaGIS

ECAP

Prague Training Visit

19.09.2016 – 23.09.2016

BOKU

Department of Landscape, Spatial and Infrastructure Sciences

Thank you for your attention…

… any questions?

BOKU University of Natural Ressources and Life Sciences, Vienna
Institute of Surveying, Remote Sensing and Land Information

Gerald LINDNER