

# UE: Scientific Methods and Writing

856.111 / 651.902

Assoc.-Prof. Stefan LANG & Hannah Augustin, MSc



University of Salzburg  
Department of Geoinformatics – Z\_GIS

# The scientific approach

Science and research

What is the scientific approach?

Example – operationalization of a research problem

Evidence

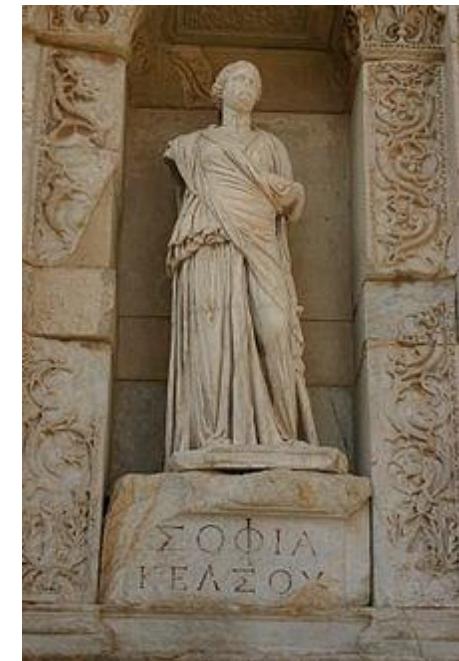
# Science

- Origin: *scientia* (= lat. knowledge)
- What makes up science?
  - Systematic and **logical approach** to discovering how things in the universe work and interrelate
  - Unlike arts, science aims for **measurable** results through observation, testing and analysis
  - Science is based on **facts**, not opinion or preferences.
  - The process of science is designed to **challenge ideas** through research.



# Scientific approach to research

- Conducting research by ...
  - Study design: scientists adopt the *scientific method* to collect measurable, empirical **evidence** in experiments related to a **hypothesis**
  - Results: aim to **support** or **contradict** a theory, rule out alternative explanations in conclusive statements



# *-logy, -sophy, -graphy*

- Many fundamental words in science, including the names of disciplines, have their origin in Greek language.
- For example: *geology, biology, philosophy, demography*, etc.

σοφία, *sofia* = wisdom

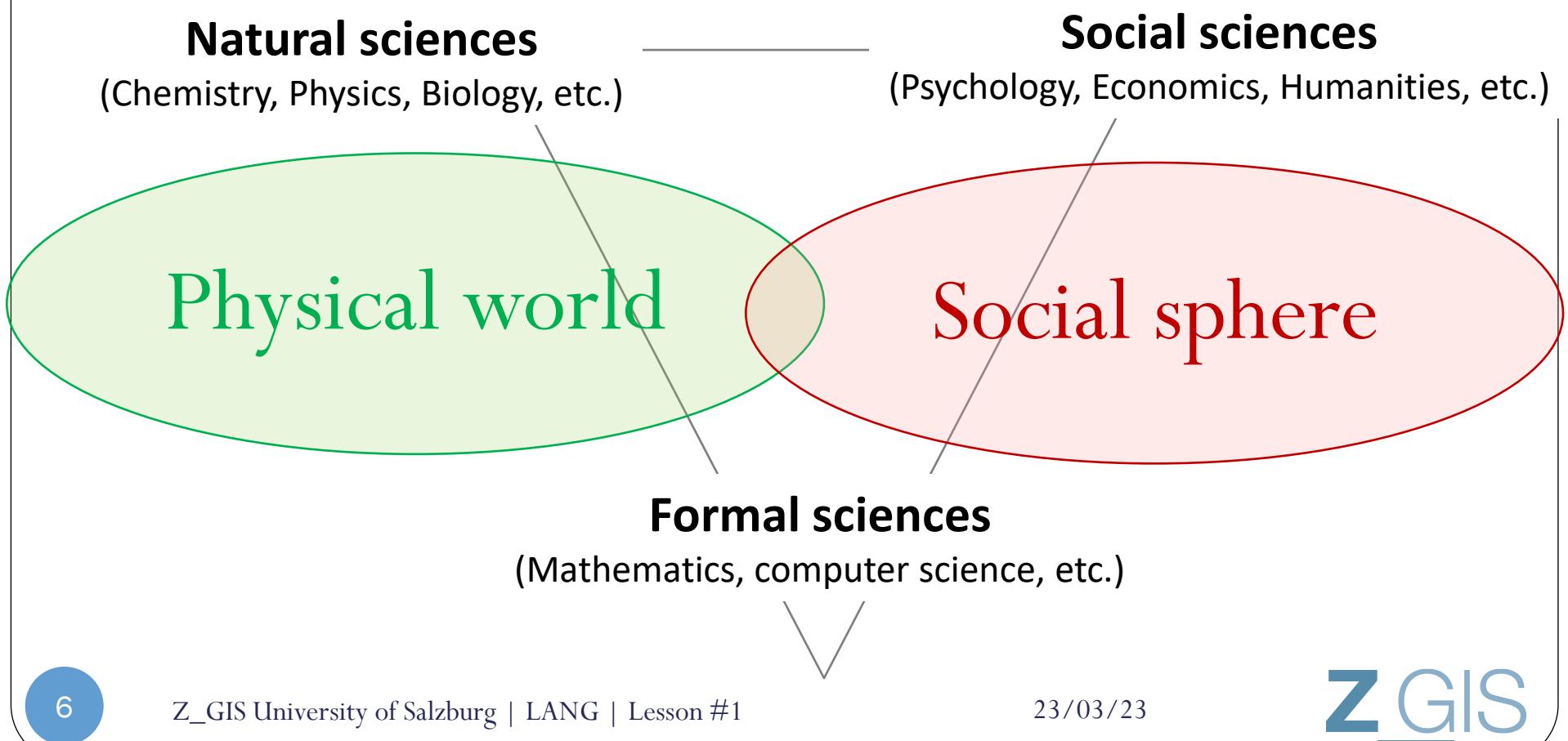
λόγος *lógos* = word



Γράφειν, *gráphein* = to write, describe

Geography =  
Γῆ - Γράφειν  
Earth description

# Branches of science



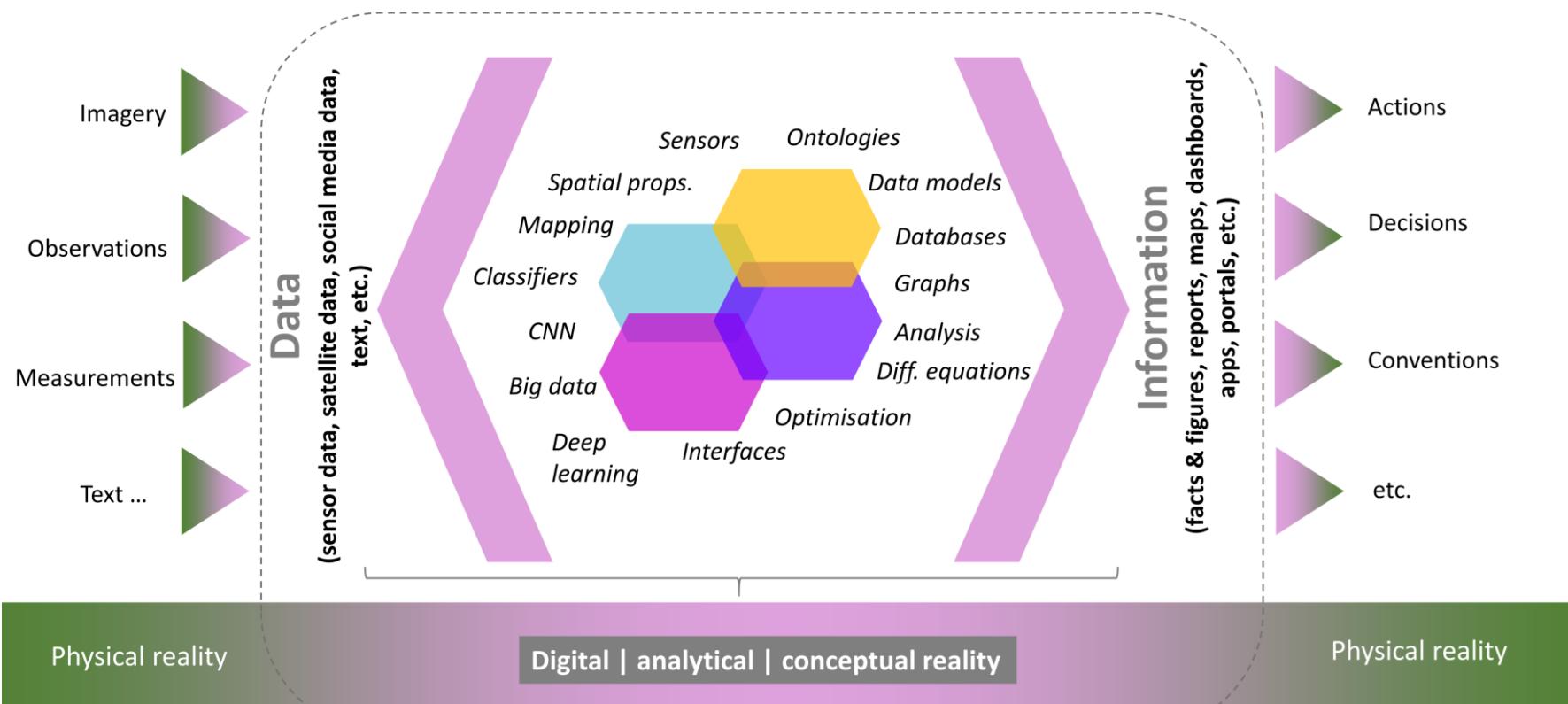
# Interdisciplinarity

- Four guiding motifs at the Paris-Lodron University Salzburg
  - Art in Context
  - Development & Sustainability
  - Digital Life
  - Health & Mind
- Faculty of Catholic Theology
- Faculty of Cultural Sciences
- Faculty of Digital and Analytical Sciences
- Faculty of Law, Business and Economics
- Faculty of Natural and Life Sciences
- Faculty of Social Sciences



# Faculty of Digital and Analytical Sciences

## Research activities @ DAS | Synergies of competences



# Salzburg – beyond Mozart

**Wolfgang Amadeus Mozart, 1756-1791**



Felix Baumgartner,  
Strato base jumper

**Leopold Kohr, 1909 - 1994**



**Christian Doppler, 1803-1853**



**Alexander von Humboldt, 1769-1859 [Berlin, 'research stay' in Salzburg]**



*"The most rewarding research projects are those that delight the thinker and are of benefit to humankind"* -  
**Christian Doppler**

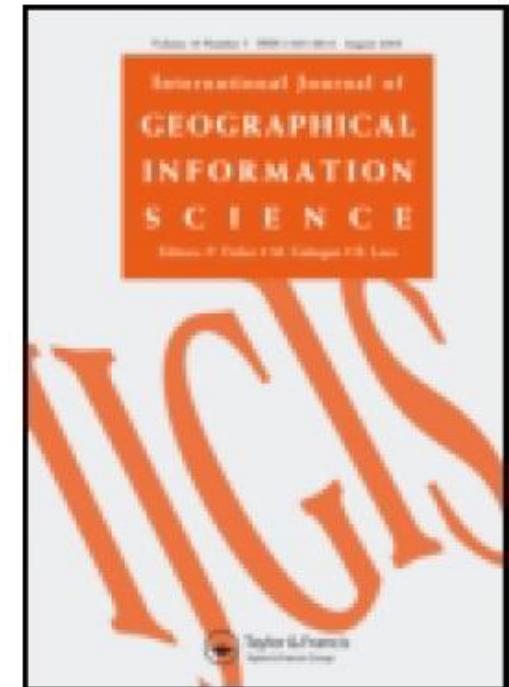


Kohn's vision of Europe of Regions (1957) – in red: today's national state boundaries

See lecture on 'Truth and objectivity' ...

# Geographic Information Science

- (no *-logy* or *-graphy* ☺)
- “Geographic(al) Information Science (short: GIScience) can be defined as the systematic study according to scientific principles of the nature and properties of information.
- GIScience is the subset of information science that is about geographic information.” (M Goodchild, 1992)



# Geographic Information Science

JOURNAL OF SPATIAL INFORMATION SCIENCE  
Number 1 (2010), pp. 3–20



doi:10.5311/JOSIS.2010.1.2

INVITED KEYNOTE ARTICLE

## Twenty years of progress: GIScience in 2010

Michael F. Goodchild

Center for Spatial Studies and Department of Geography  
University of California, Santa Barbara, CA 93106-4060, USA

July 27, 2010

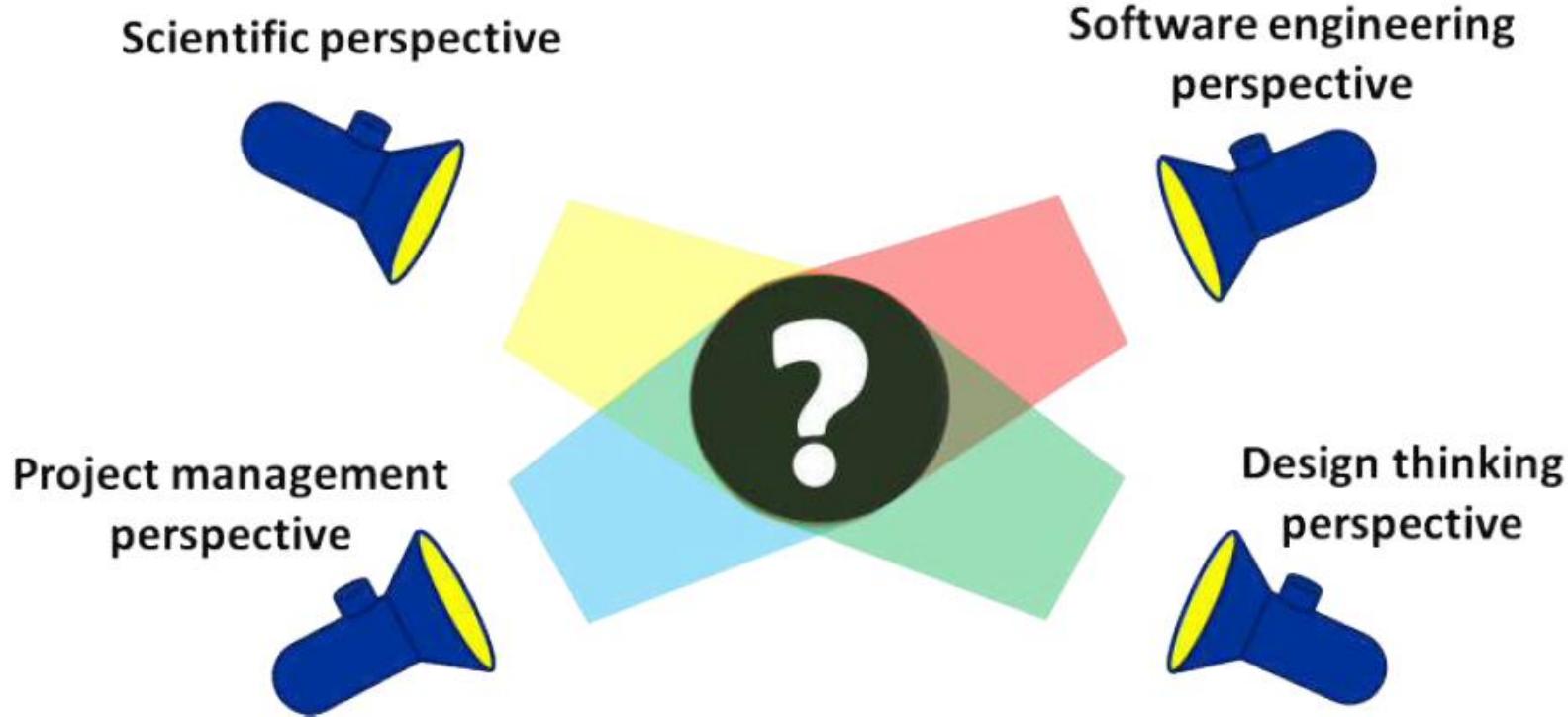


M Goodchild at the 30 years anniversary of Z\_GIS (2018)

---

**Abstract:** It is 20 years since the term “geographic information science” was suggested to encompass the set of fundamental research issues that surround GIS. Two decades of GIScience have produced a range of accomplishments, in an expanding literature.

# Perspectives to research problems

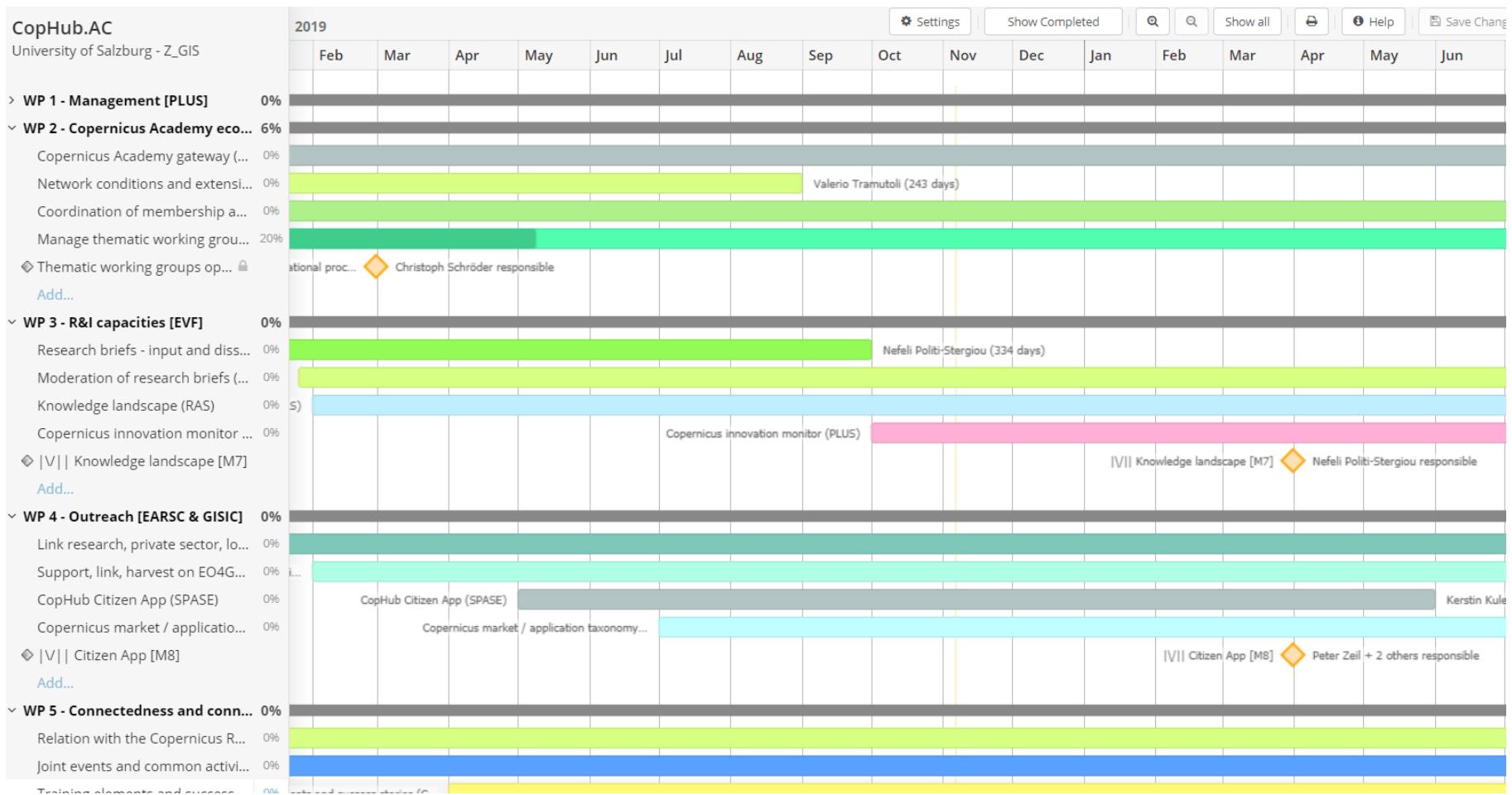


F Albrecht (2019) A conceptual framework for modelled visibility information, PhD thesis,  
University of Salzburg.

# Perspectives to research problems

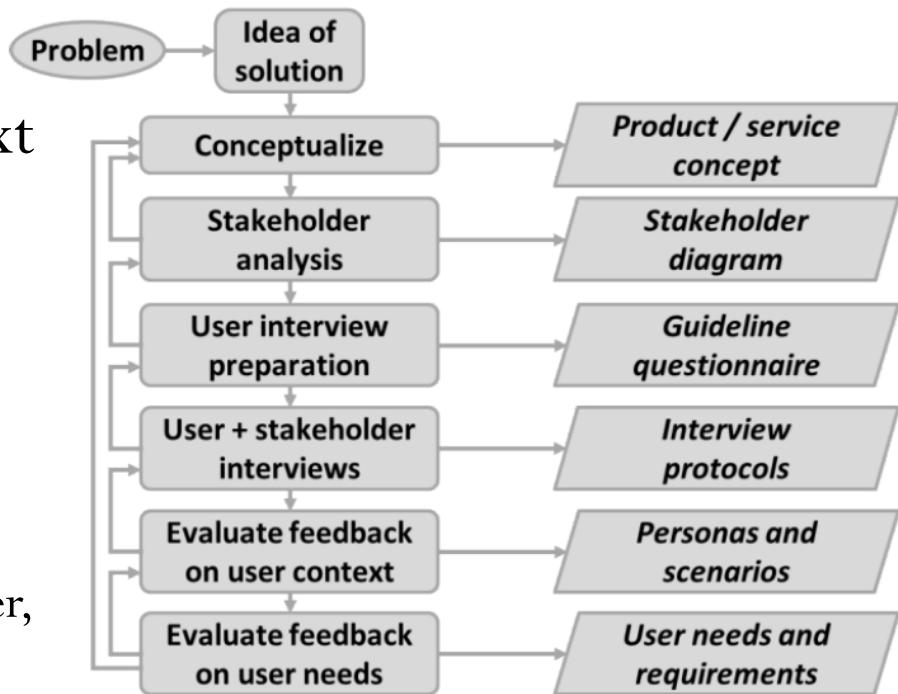
- **Scientific** perspective | (see above); main driver: **curiosity**
- **Project-driven** perspective | considering necessary research tasks a manageable project elements with given resources (time & effort); main driver: **achievability**
- **(Software) engineering** perspective | attempt to solve a problem with appropriate software product; main driver: **feasibility**
- **Design thinking** perspective | solution is able to serve the needs of a user or group of users; main driver: **purpose** (desirability)

# Project management – Gantt chart

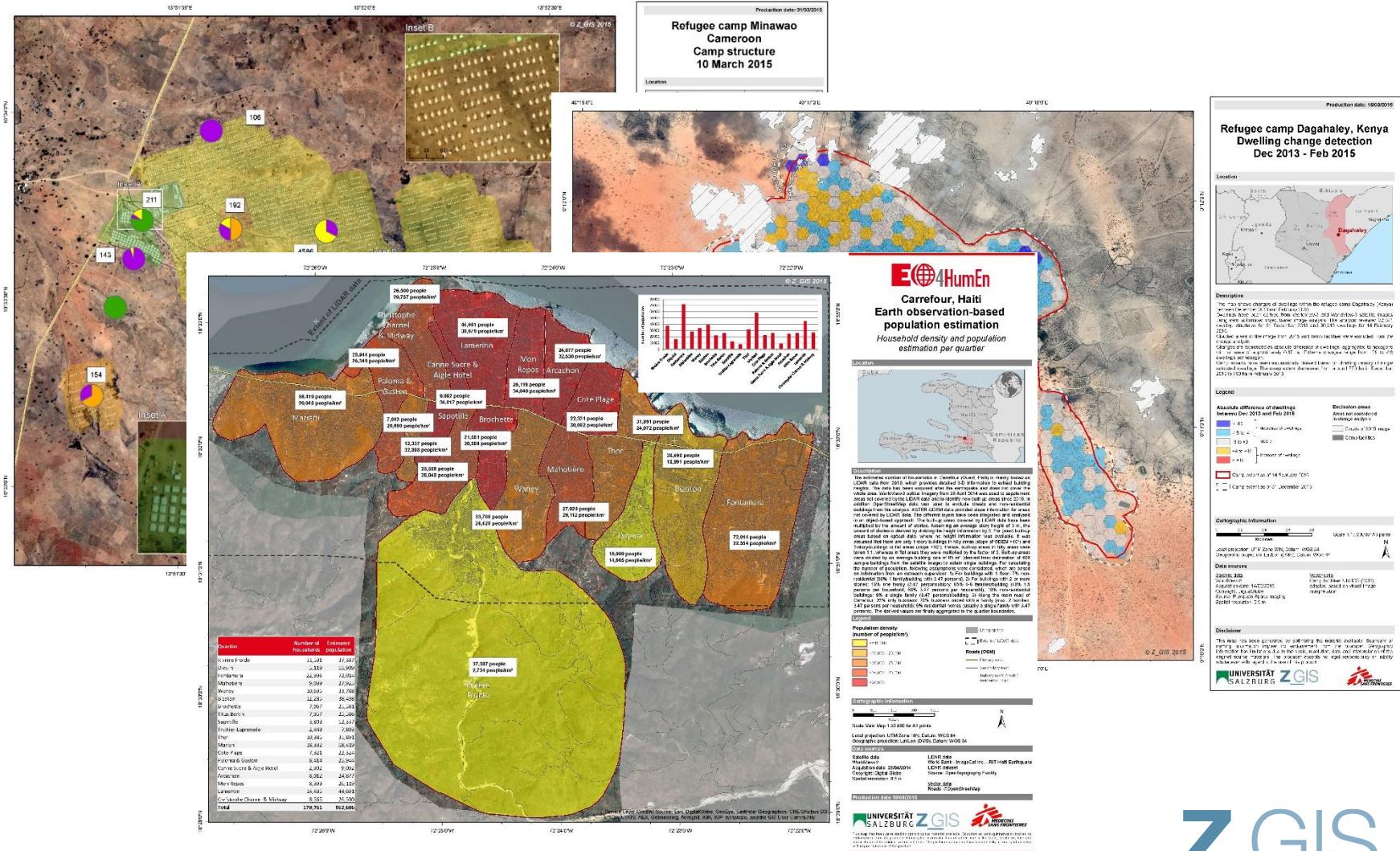


# Design thinking – user needs

- User-centred design (UCD)
- (a) understanding and specifying the user context
- (b) definition of user requirements,
- (c) producing design solution
- (d) design evaluation (Saffer, 2007; Wealands et al. 2007)



# User needs - examples

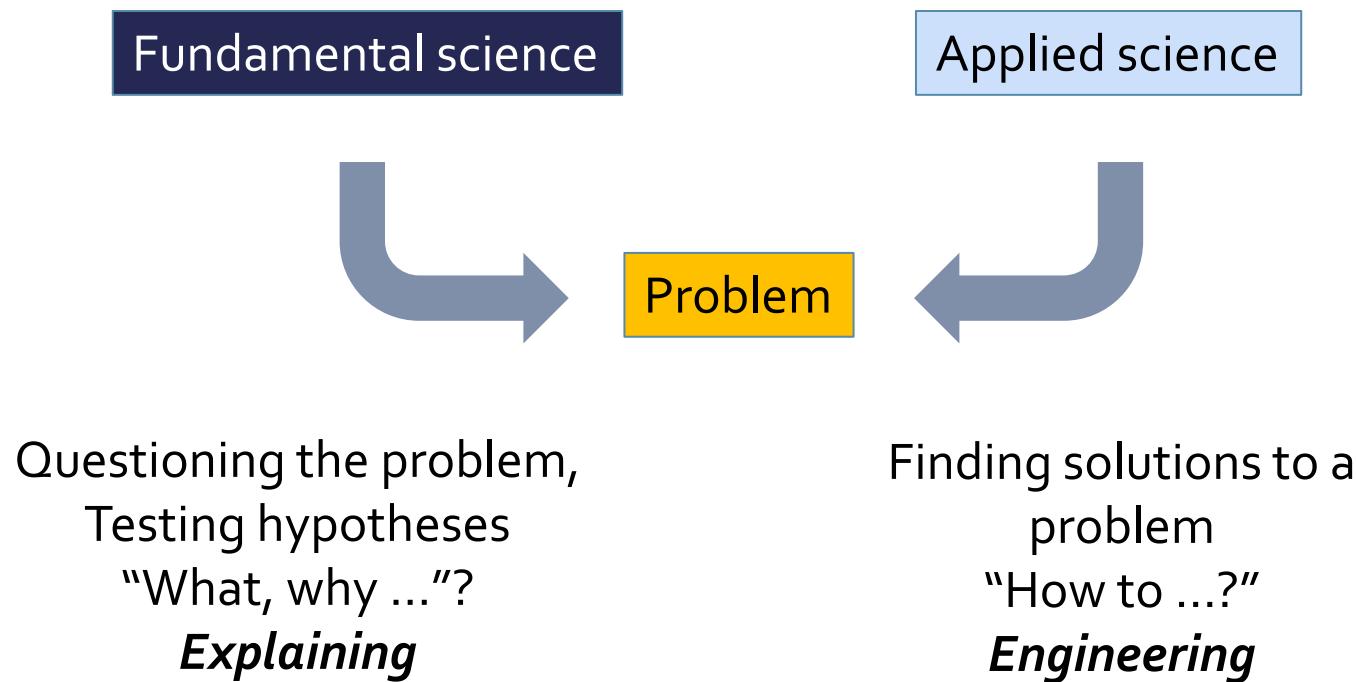


# Human-centred design ... 'Youber'



# Fundamental vs. applied science

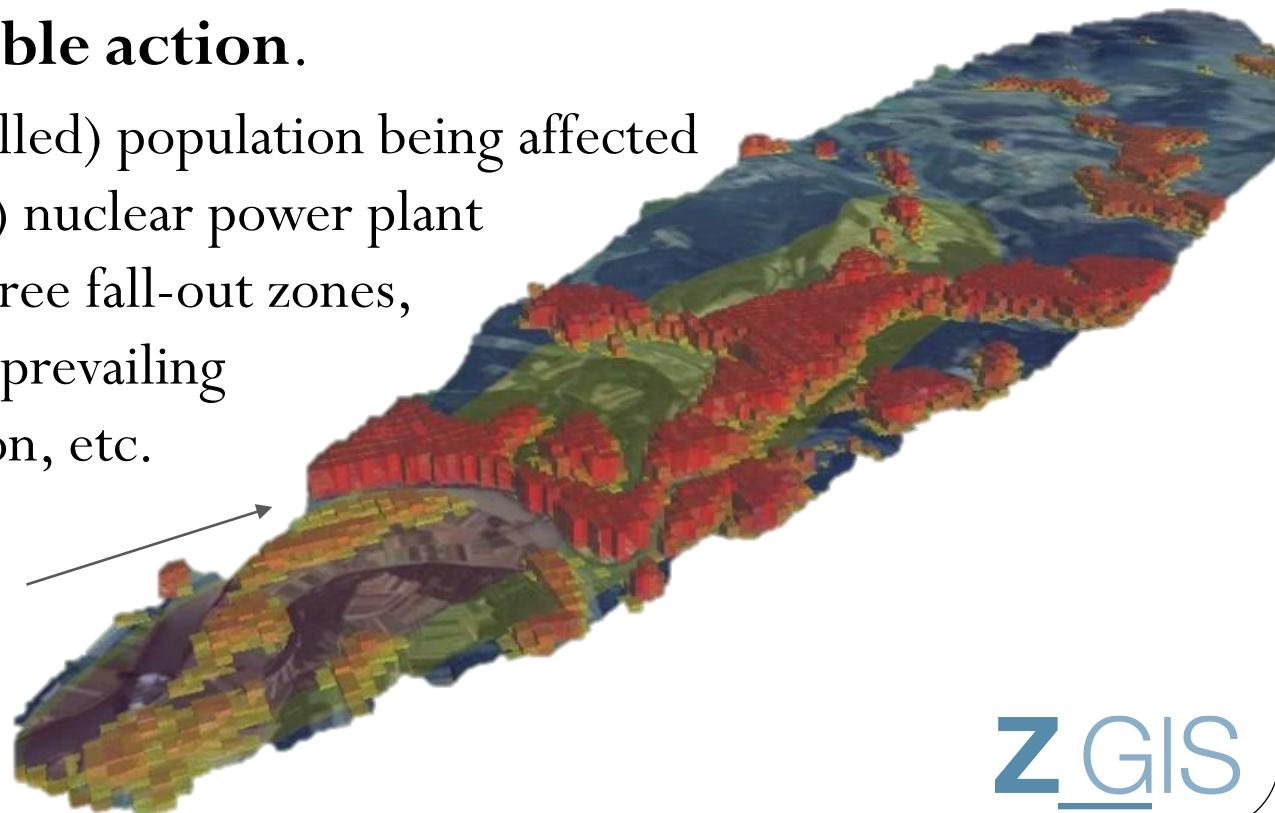
- University (U, Univ) vs. University of Applied Science (Fachhochschule, FH)

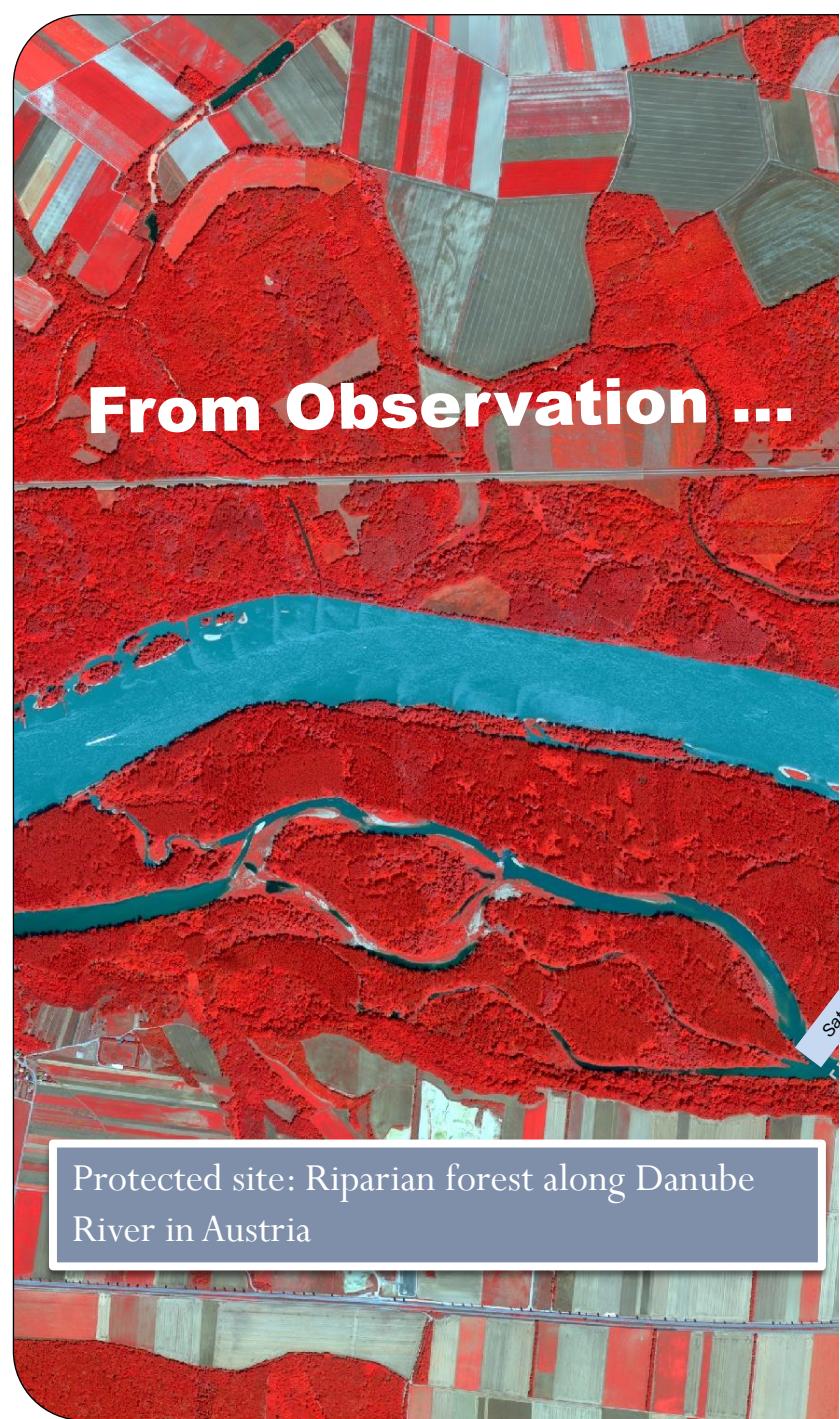


# Aim of science?

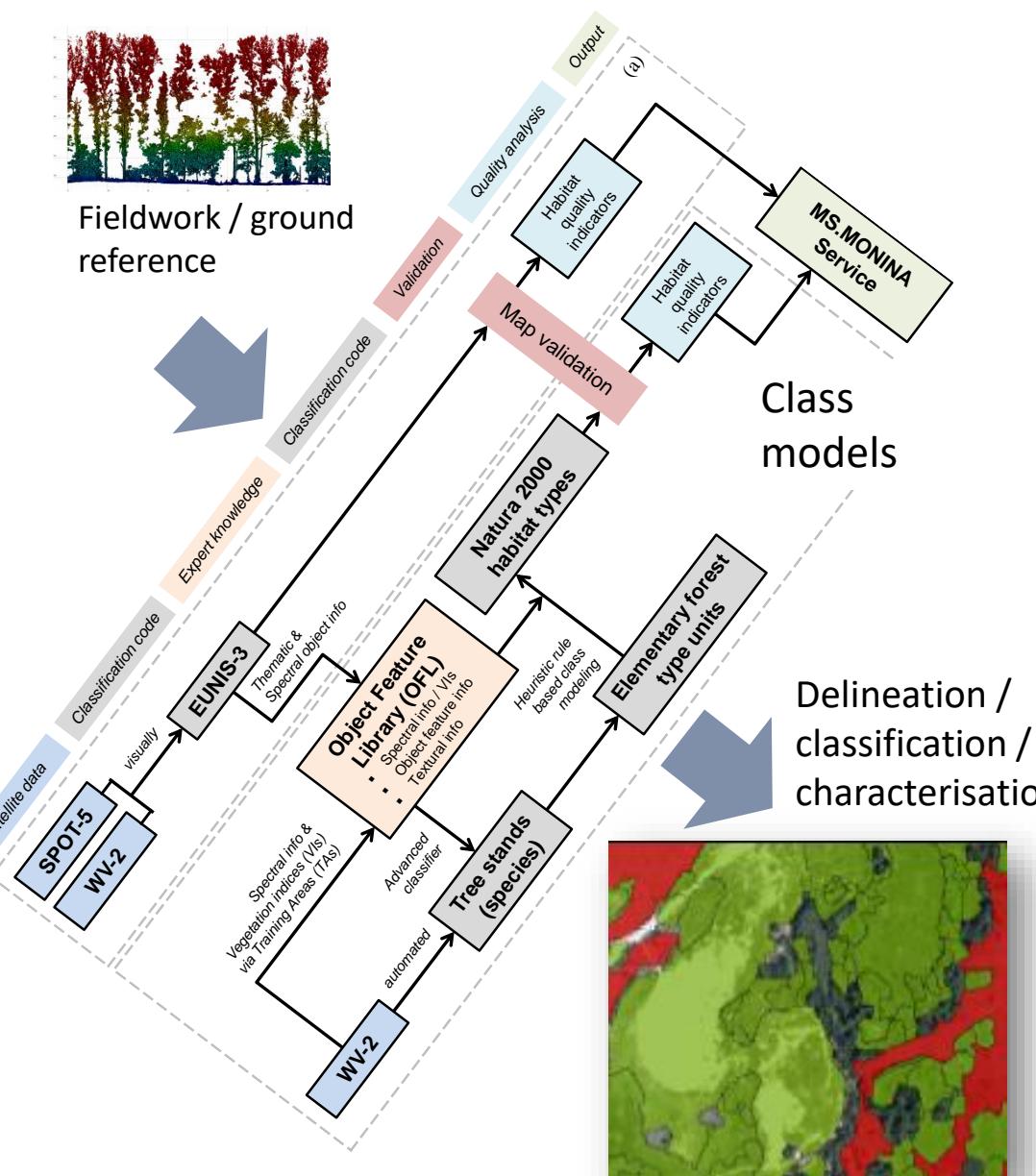
- Not an **end-in-itself**
- From **observations** to **knowledge** to **action** ...
- Today we speak of **informed decisions** or **knowledgeable action**.
  - Here: (modelled) population being affected by (fictitious) nuclear power plant accident – three fall-out zones, according to prevailing wind direction, etc.

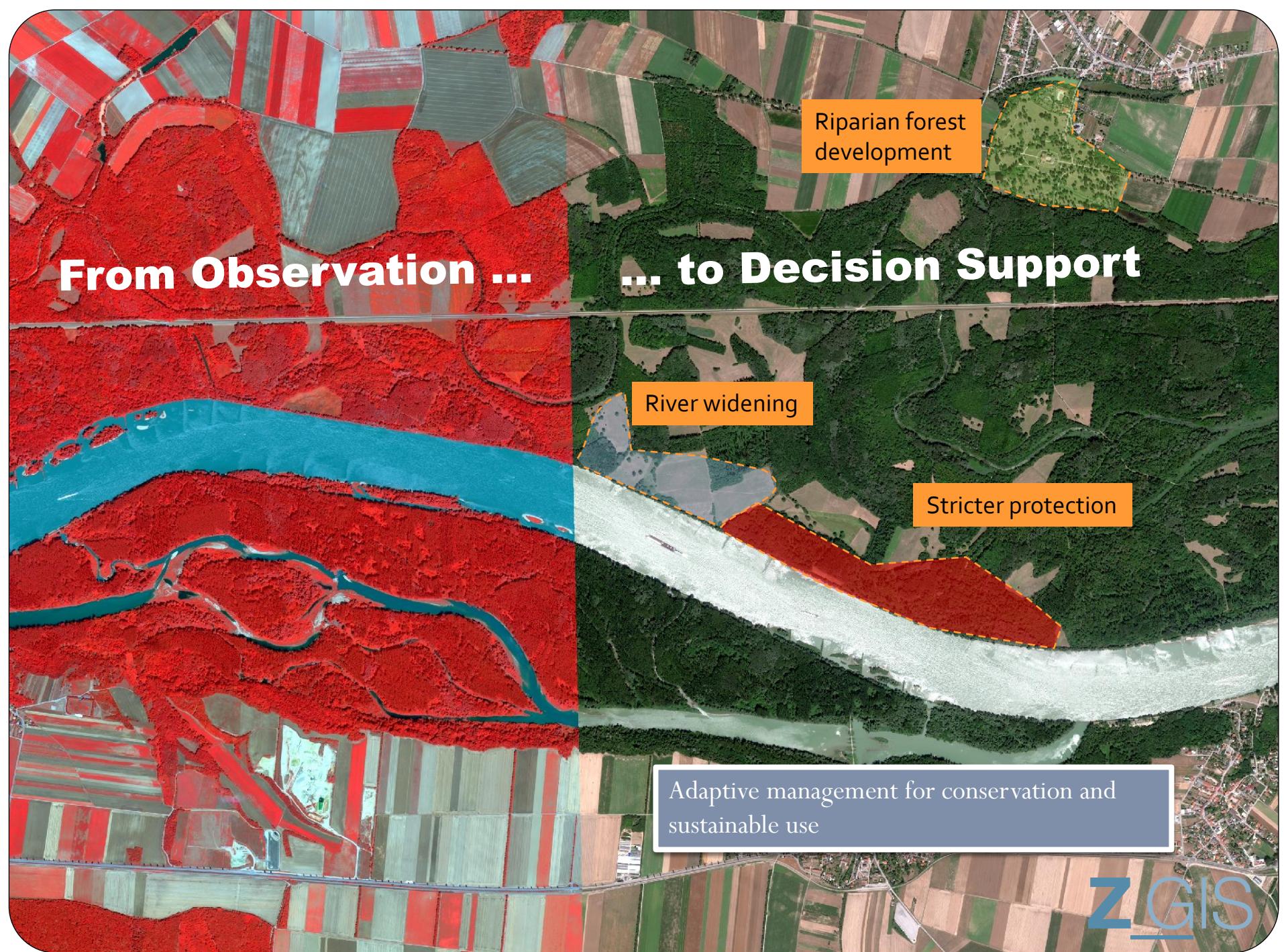
Trans-boundary (DE/CH)





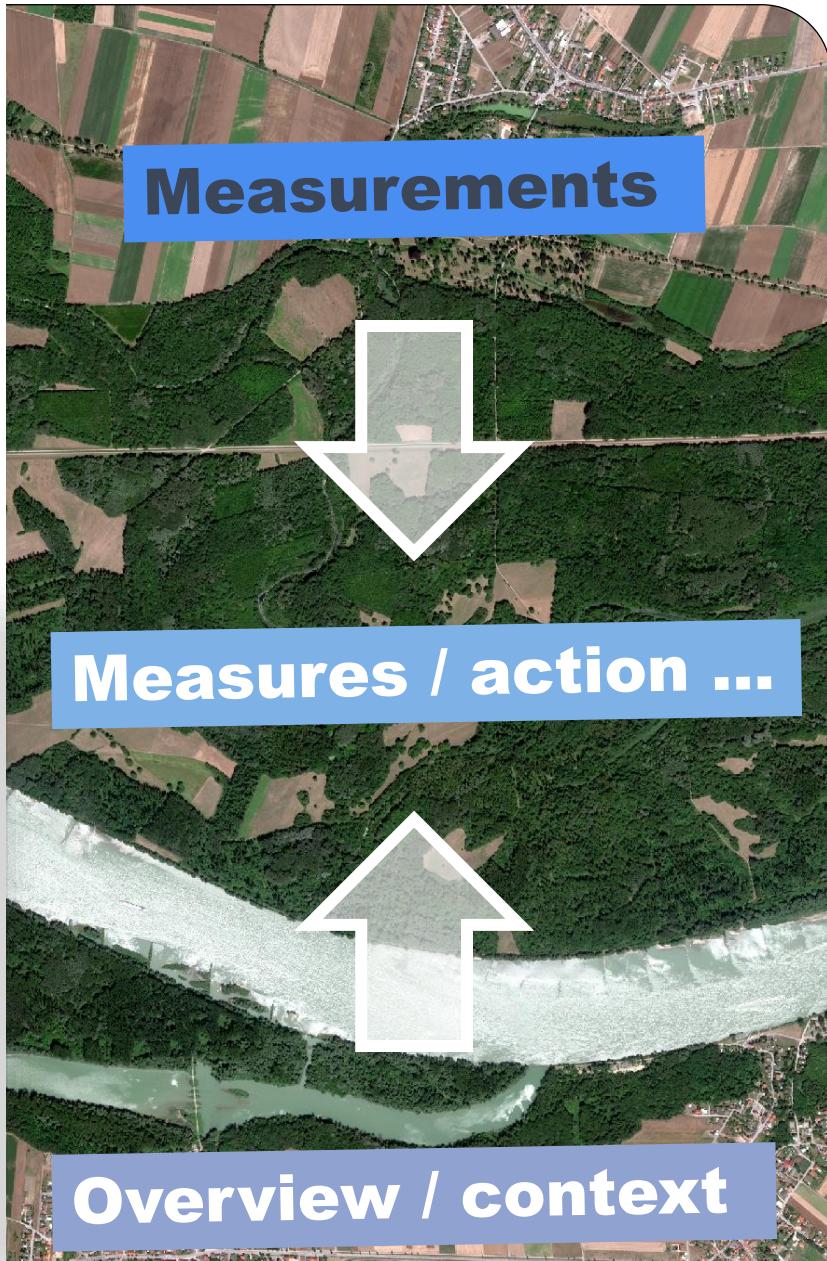
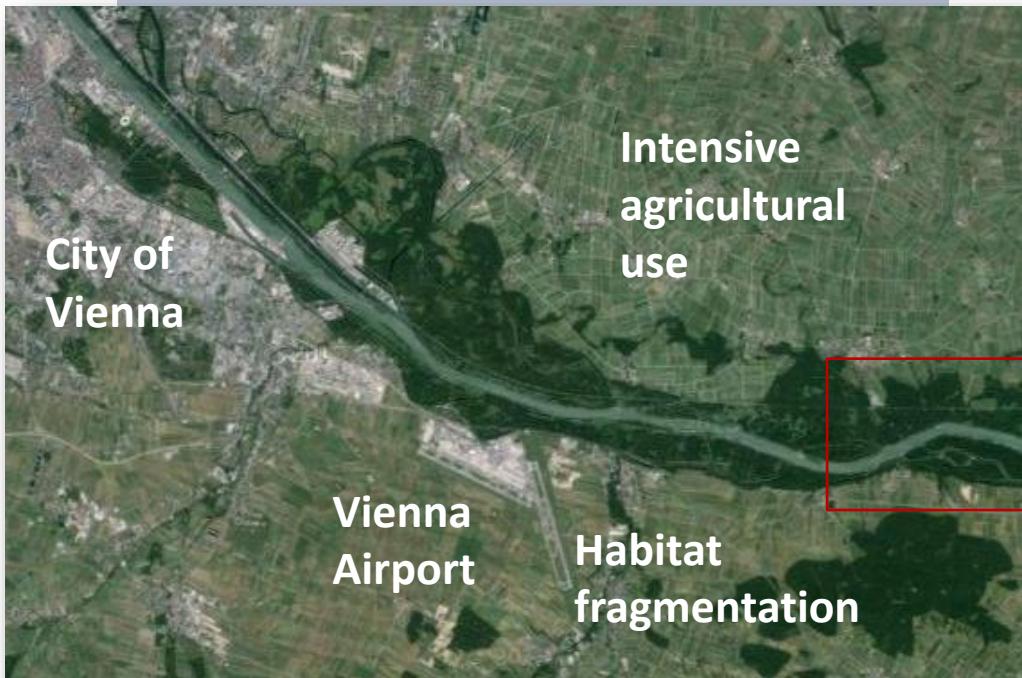
## - using advanced tools and methods -





**Protected sites are not islands, but embedded in larger context ...**

- Threats and pressures induced by humans
- Habitat loss and fragmentation
- Settlement and infrastructures
- Agricultural activities
- [climate change – shift in habitat]



# Research questions

- Research carried out in order to ...
  - overcome identified research gap
  - solve a particular problem
- More general
  - research objectives (to be met within study, project)
  - Overall aim (motivation, drivers, higher goals)
- Research questions should ...
  - break down a more complex issue, problem etc.
  - be approachable and ideally answerable
  - be concrete, manageable (also time-wise)

Questions should be answerable, but not simply stating Yes/No ...  
otherwise the answer is usually "Yes"  
E.g. "*Can land use change be analysed using satellite data?*"

Research questions ↔ Aims & objectives

Scientific paper

Research Proposal

# What about your research questions?



Check your essay for possible questions ...

- *Are they answerable?*
- *Are they well ‘scaled’ to the scope of the study?*
- *Are they well ‘granulized’?*

# Scientific approach

Personal observation  
& thinking

Findings of peers  
(publications!)

! (scientific)  
problem !

? Research question ?

Method of investigation  
Formulate hypothesis

Observations and measurements  
recorded during investigation → data

Analysed and compared with other results

Synthesis, order (classification), generalisation

Supports  
hypothesis ...

✗ ... or does  
not support

# Scientific approach

Theory

*Universal laws*

? Research question ?

Set of evidence-proven hypotheses  
Accumulated observations on the subject

... can be **challenged** at all times on all levels!

- Due to **new findings**
- Due to **scientific misconduct** (e.g. data fabrication)

Writing ensures that others share my hypotheses and I share others' ...  
→ Avoids **duplication**  
→ Contributes to **knowledge**

# Law – theory – observation?

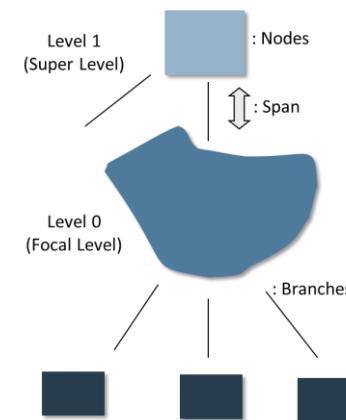
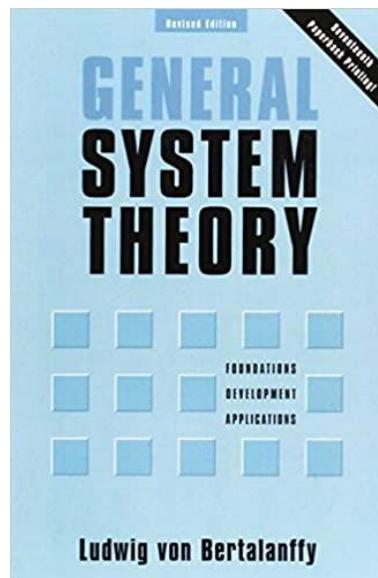
Law

Theory

Observation

*"The whole is more than  
the sum of its parts"*

?



# Law – theory – observation?

Law

Theory

Observation

- near and related
  - near = geographical similarity
  - related = attribute similarity
- fundamental principle underlying spatial autocorrelation, spatial interpolation, local analysis

*"near things are more related than distant ones"*

?

L Anselin



# Operationalisation

---

...of a research problem

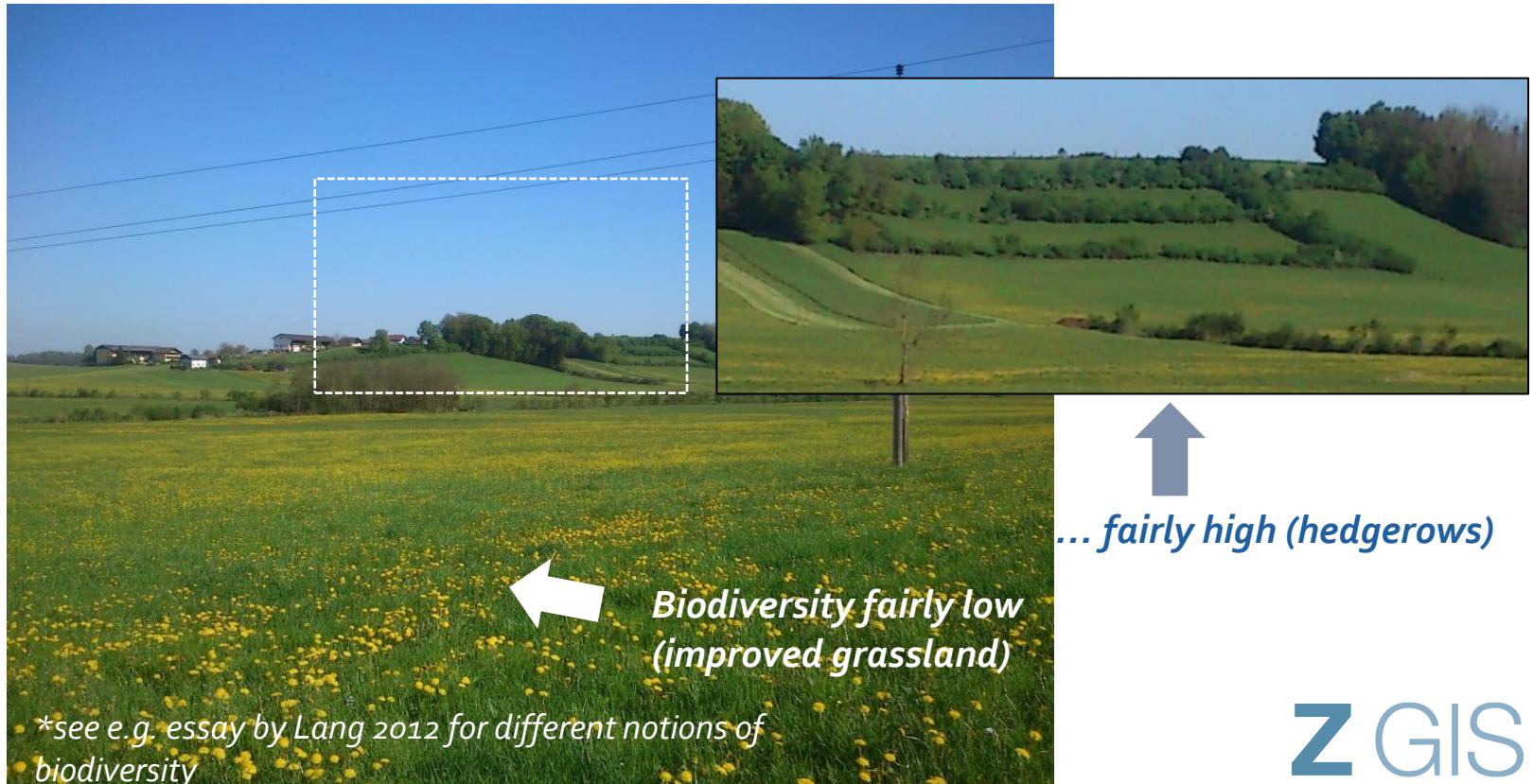
# Example – Land cover classification

- **Problem:** Does **biodiversity** vary within a given study area?



# Example – Land cover classification

- **What is biodiversity?\***
  - Biodiversity [is commonly agreed as] the variety of life forms / of species



# Example – Land cover classification

- How to **operationalize** this question?
- We need to clarify:
  - What means ‘biodiversity’?
  - Can we measure biodiversity directly or using proxies/indicators?
  - What theoretical framework, what methods to be used?
  - What data, what tools to be used?
  - Etc.

# Example – Land cover classification

- **Operationalization**

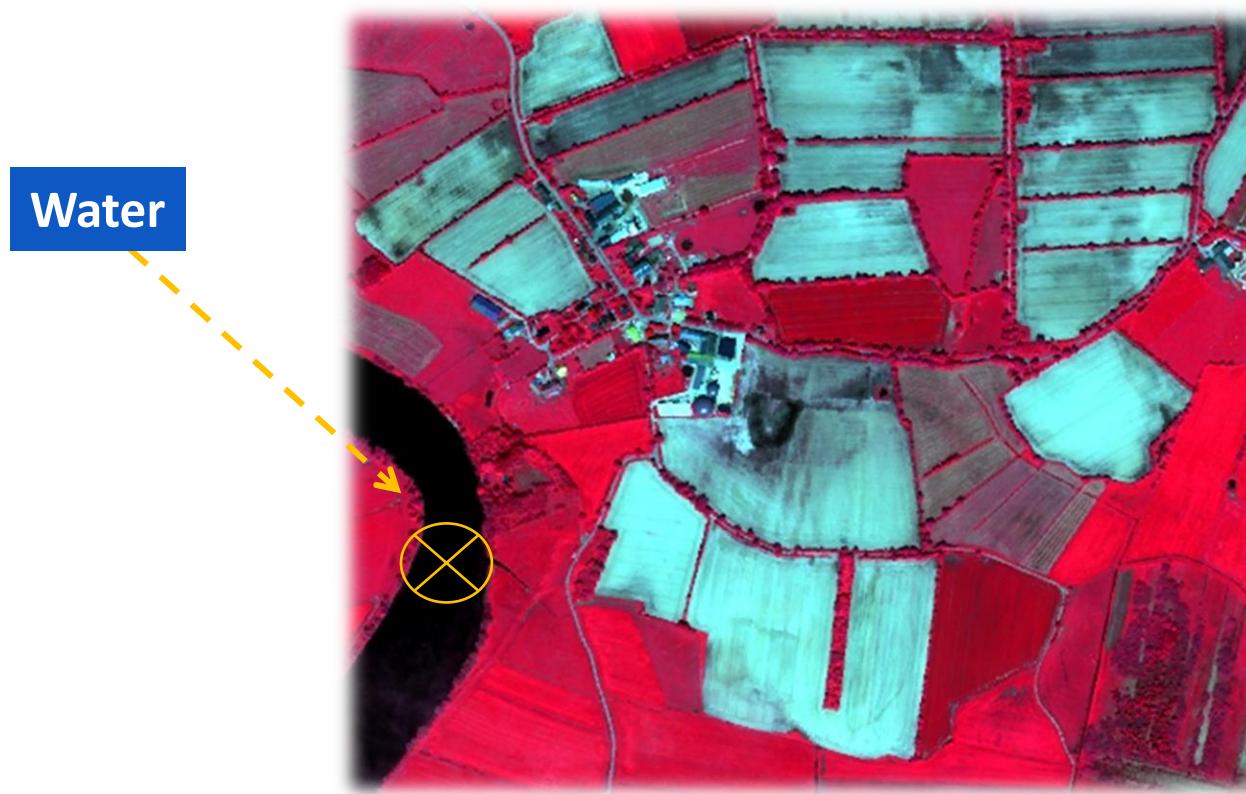
- Biodiversity *can be approximated* by studying different land cover types, e.g. based on an airphoto or satellite image (false colour!)



= area of  
interest

# Example – Land cover classification

- **Method of investigation:** using satellite remote sensing data and perform a multi-spectral classification



# Example – Land cover classification

- Law: physical principles (laws of radiation, etc.)

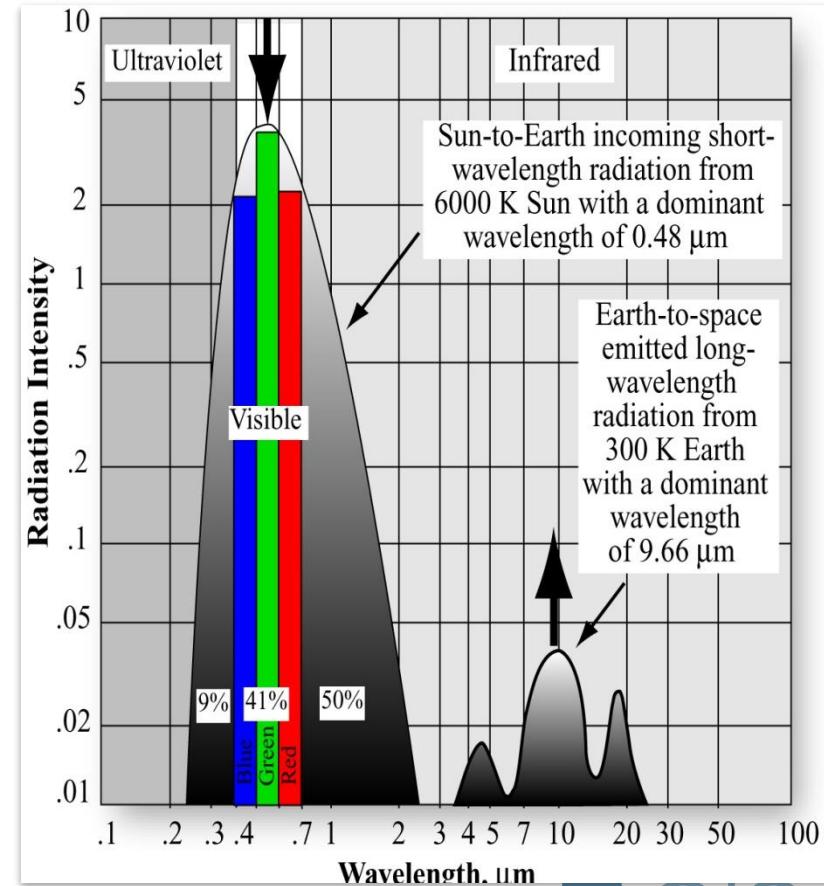
## Stefan Boltzmann's Law

The hotter a body, the more energy is emitted

## Wien's Displacement Law

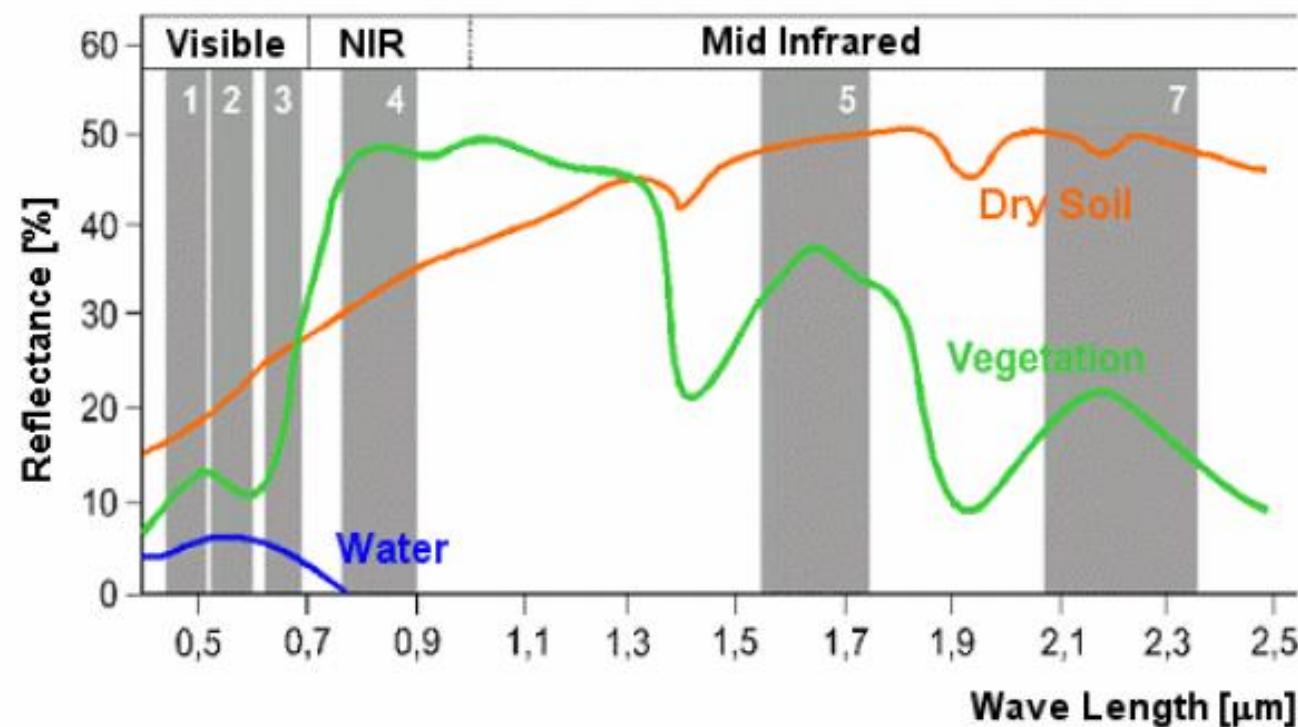
The hotter a body, the shorter the wavelength of the maximum radiation

→ These laws apply to (hypothetical) black bodies



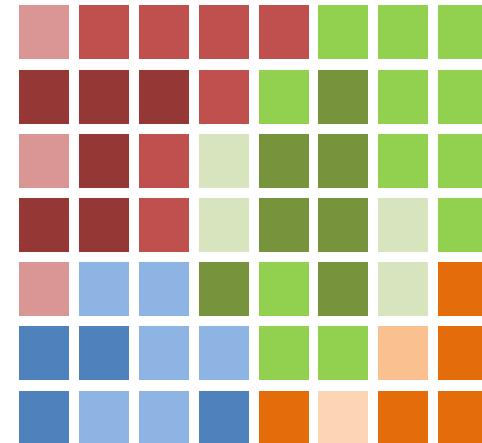
# Example – Land cover classification

- **Theory:** spectral behaviour of different land cover types, green vegetation, etc.



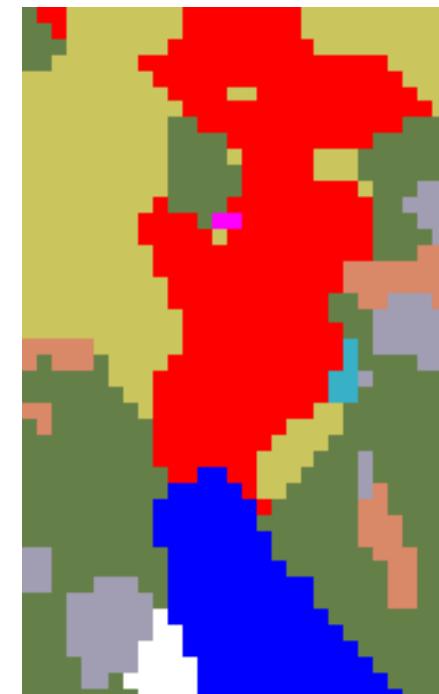
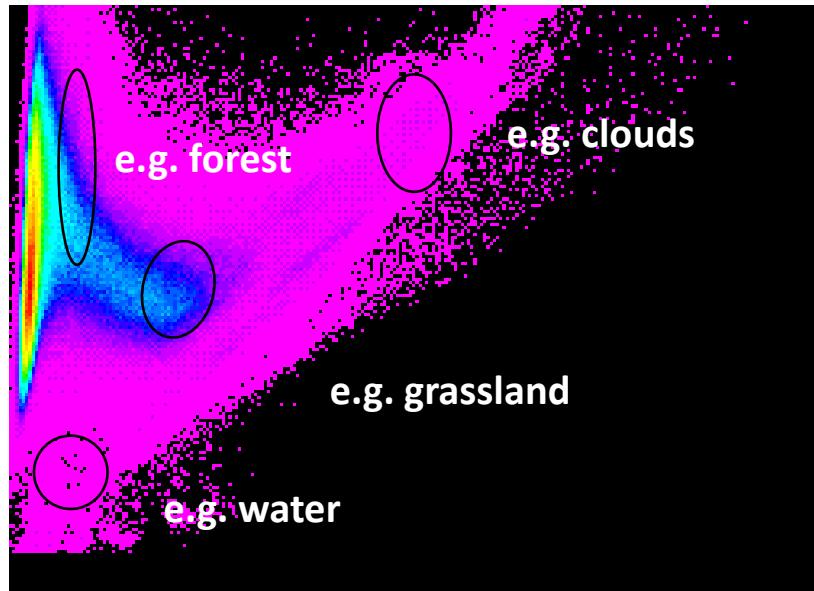
# Example – Land cover classification

- **Method 1:** remote sensing and image processing
  - Using a sensor device on a satellite platform to measure radiation and convert it to ‘digital numbers’
  - Digital numbers can be converted to physical units of measurement (radiance) and classified into categories



# Example – Land cover classification

- **Method 2:** supervised classification
  - statistical approach assuming that similar spectral values represent the same land cover type in a data feature space



# Evidence

---

# How to find evidence?

- Observations
  - **Quantitative** (measurements)
  - **Qualitative** (interviews, descriptions, etc.)
  - Depends on discipline, scientific approach, tradition ...

*“Quod gratis asseritur, gratis negatur”*

“What can be asserted without evidence [costs] can be dismissed without evidence.”

(Hitchens's razor)



# How to find evidence?



BBC Sign in

News Sport Weather Shop Earth Travel Mo

## NEWS

Home Video World UK Business Tech Science Stories Entertainment & Arts

Asia China India

### Who will help Myanmar's Rohingya?

10 January 2017

Asia migrant crisis

f t m Share

MUNIR UZ ZAMAN/AFP

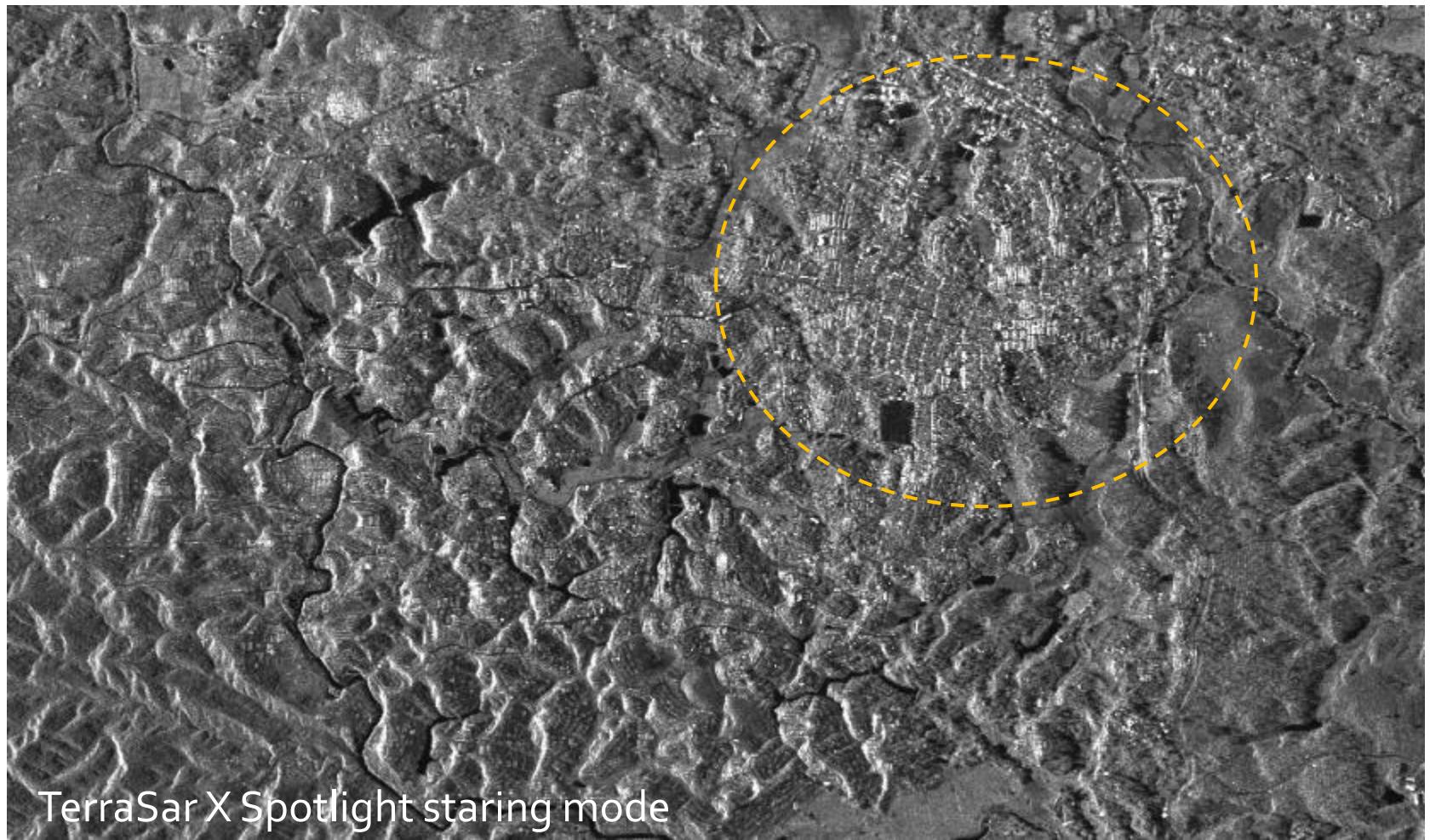
Tens of thousands of Rohingya have fled to refugee camps in Bangladesh since October

# How to find evidence?



Sentinel 2 – Level 1C product

# How to find evidence?



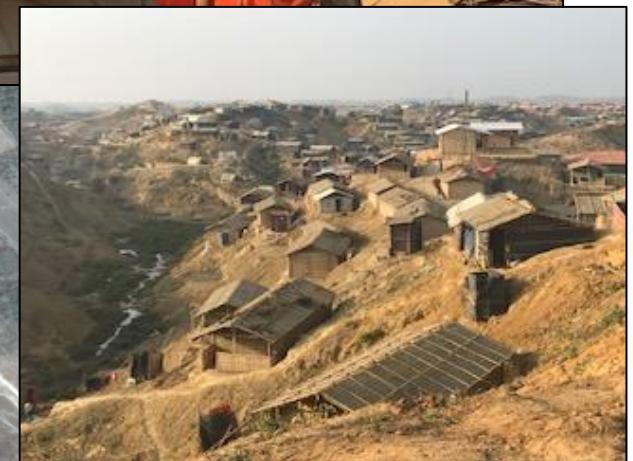
TerraSar X Spotlight staring mode

# How to find evidence?

Kutupalang\_Feb2018\_AH\_m2.jpg



Latitude: 21,183217° N  
Longitude: 92,152139° E  
Altitude: 18,5980392156863m  
Direction: 32,6761487964989°  
Timestamp: Samstag, 24. Februar 2018 - 15:34:03



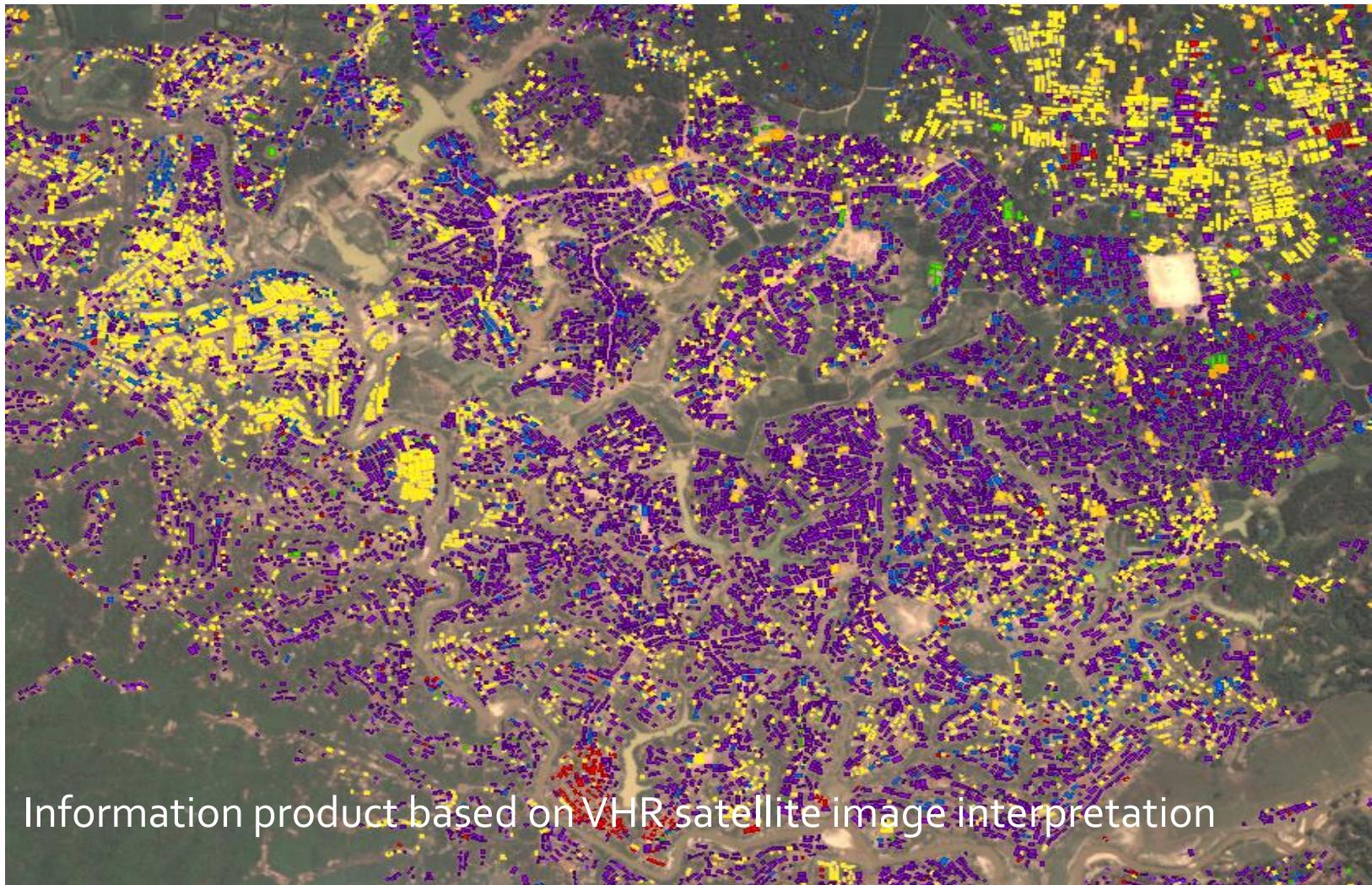
Ground reference ('truthing')  
Location of photographs

# How to find evidence?



Drone imagery, Feb 2018

# How to find evidence?



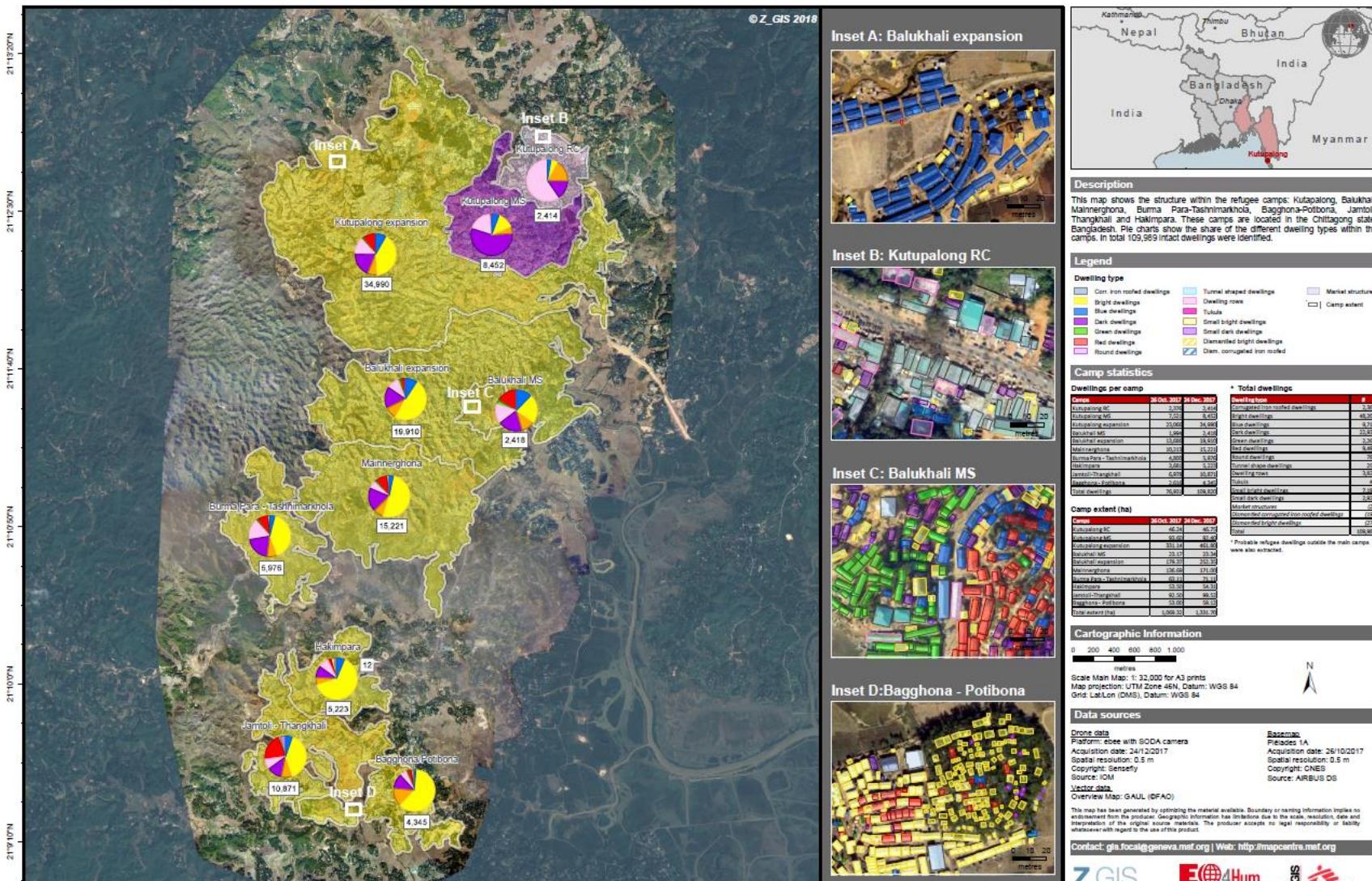
Information product based on VHR satellite image interpretation

# Bangladesh - Kutupalong and surroundings

## Camp structure (24 December 2017)

Production date: 26/01/2018

Product N: BGD-2018-02-POP-CST



Z GIS

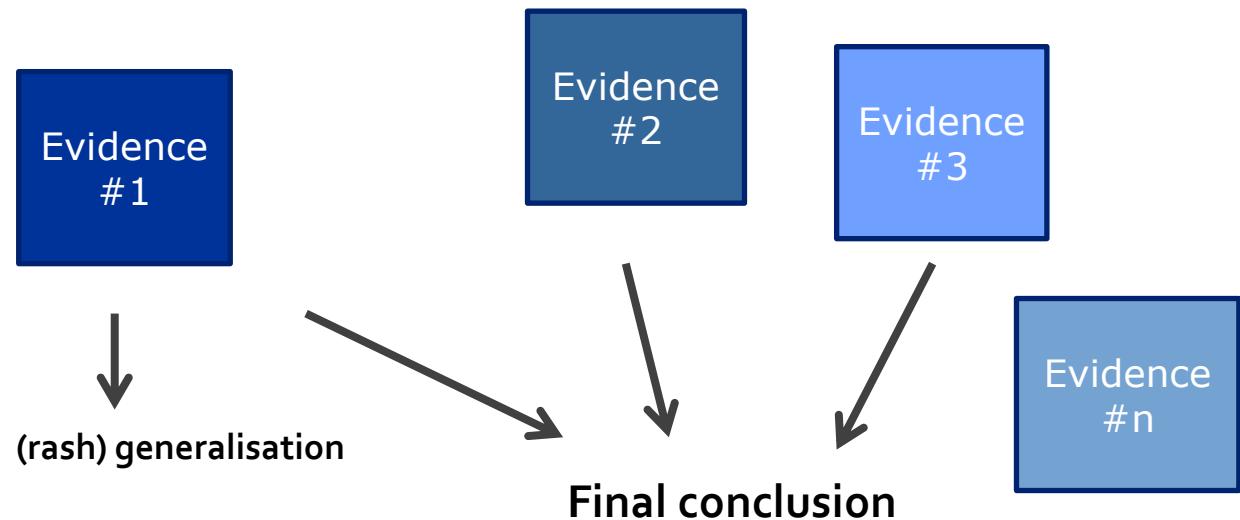
E4Hum

GSI

Z GIS

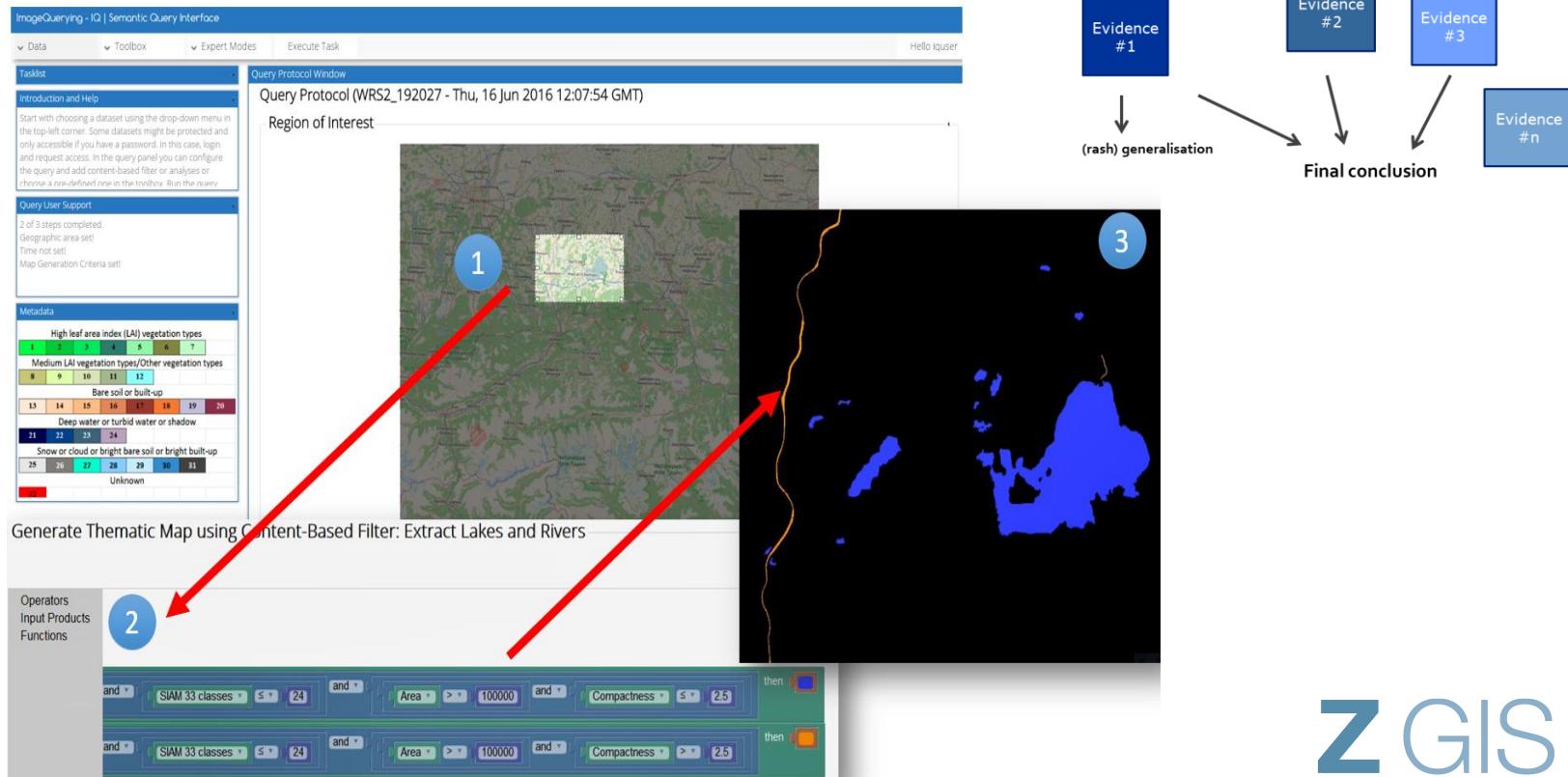
# Convergence of evidence

- A set of different evidences lead to (a more solid) conclusion  
→ ‘scientific explanation’
- Beware of rash generalisations
  - “*I have heard that ...*”



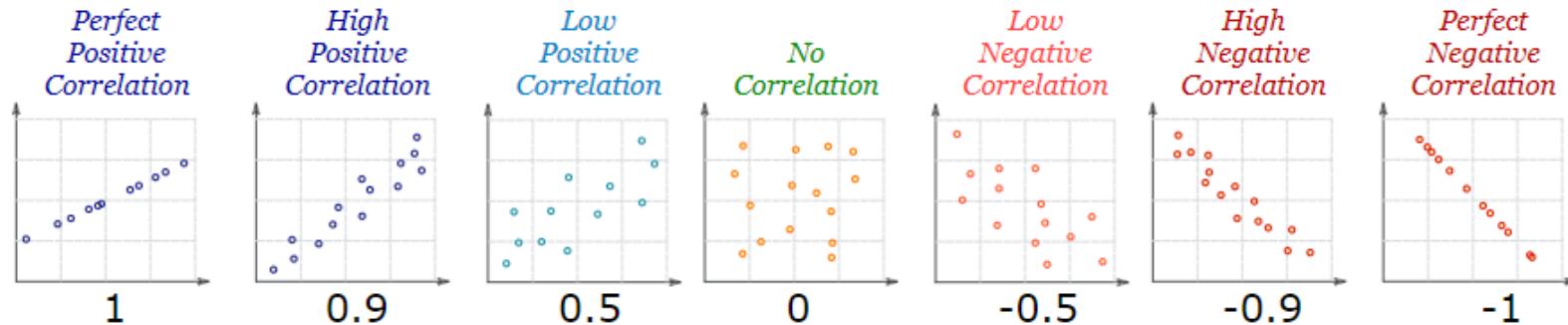
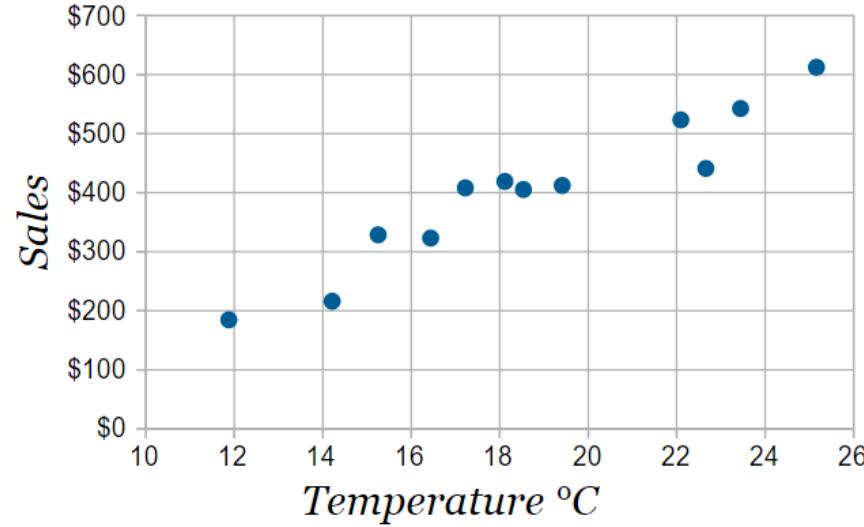
# Convergence of evidence

- E.g. semantic querying system of satellite imagery
- Necessary, (not) sufficient conditions to identify an object as a lake (colour [surface material], shape)



# Correlation as evidence?

- Dependence between two (or more variables)
- Correlation is often used as evidence, but ...
- Correlation  $\neq$  causality!



<https://www.mathsisfun.com/data/correlation.html>

# Essay

- Free essay
  - Freely associating, imaginary, etc.
  - No headings (only generic like ‘introduction’)
  - More implied than stated
  - 5 para rule for initial structuring
- Scientific essay
  - Well structured
  - Systematic approach
  - Headings required
  - Explicit statements

**Def (scientific essay)** after Barras 2002:  
*“An essay in science or engineering is a vehicle for conveying information and ideas; it is a short written account of a well-defined subject. It is clear and decisive, systematic and comprehensive with the parts signposted by carefully chosen headings.” [p 50]*

# Assignments

