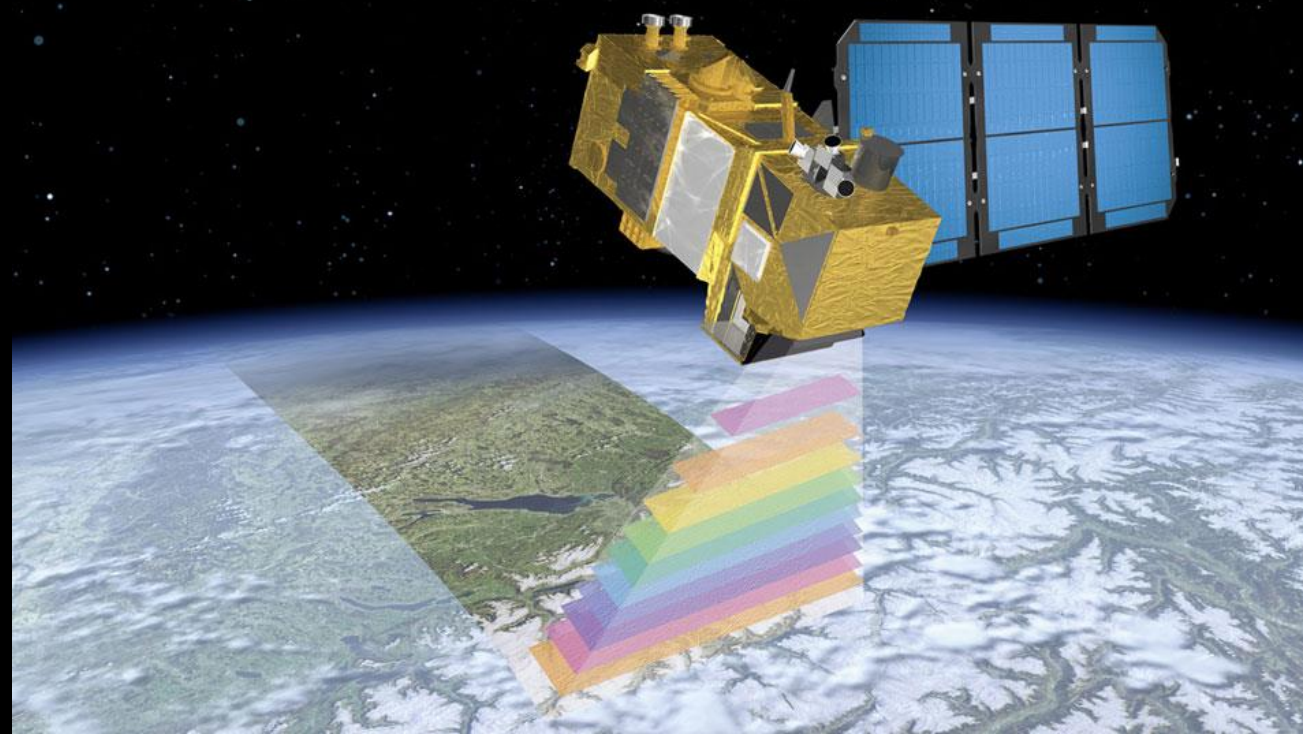
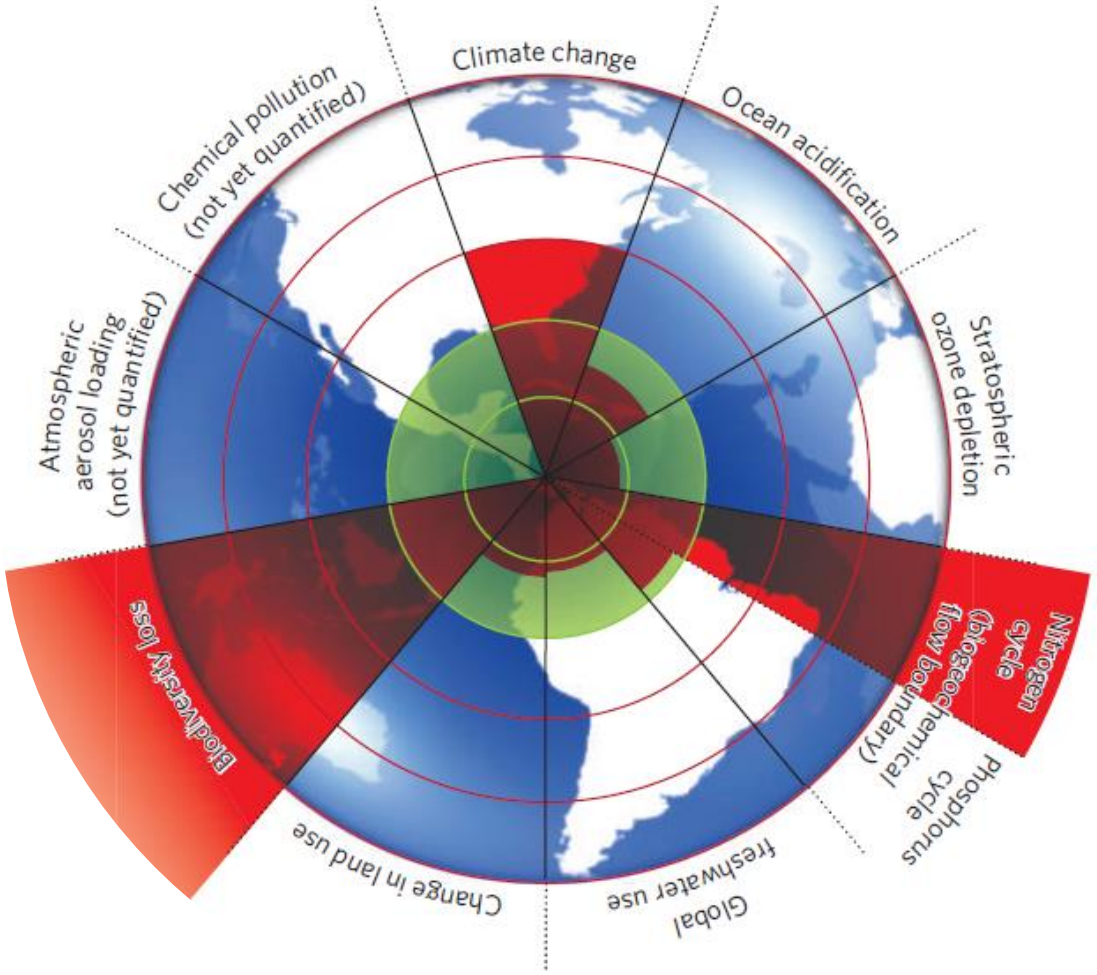
ADVANCED COURSE | CIBIO/INBIO | 18th – 20th MARCH 2019, VAIRÃO, V. CONDE
MODELS IN INVASION ECOLOGY: CHALLENGES AND APPLICATIONS

DOWN ON EARTH AND UP IN THE SKY – APPLICATIONS OF SATELLITE AND UAV VERY-HIGH RESOLUTION IMAGERY FOR INVASION MAPPING AND SURVEYING

João Gonçalves
Renato Henriques

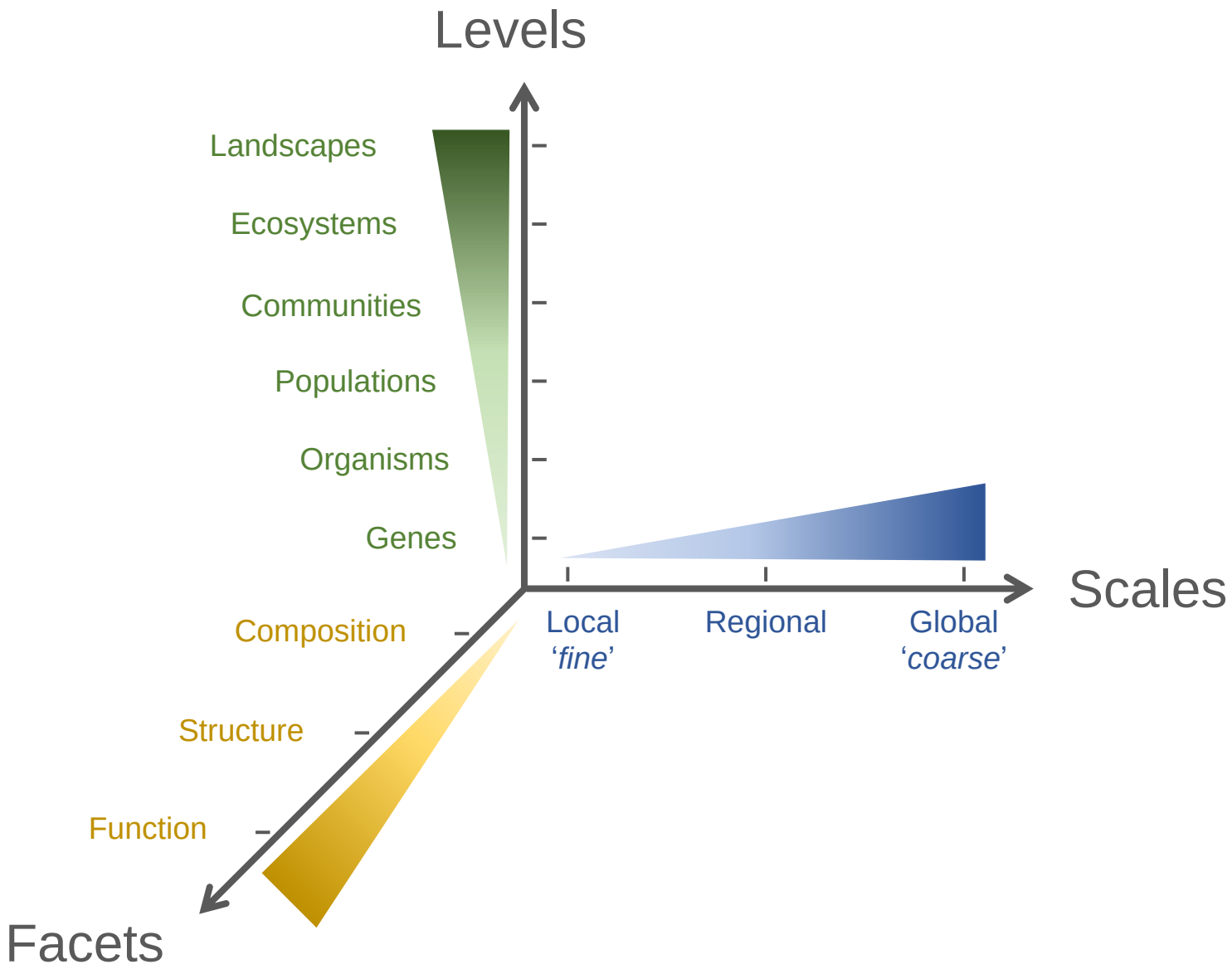


ECOLOGICAL CHANGE IN THE ANTHROPOCENE



- Widespread changes in biodiversity motivated by synergistic impacts of multiple environmental changes: climate and land use change, invasive species, etc
- ‘Re-distribution’ of life on Earth
- Pervasive changes in ecosystem functioning and their services
- A **safe-operating space** for Earth ecosystems
- **Assessing and monitoring biodiversity is more crucial than ever**

THE 'MULTI-DIMENSIONAL' CONCEPT OF BIODIVERSITY



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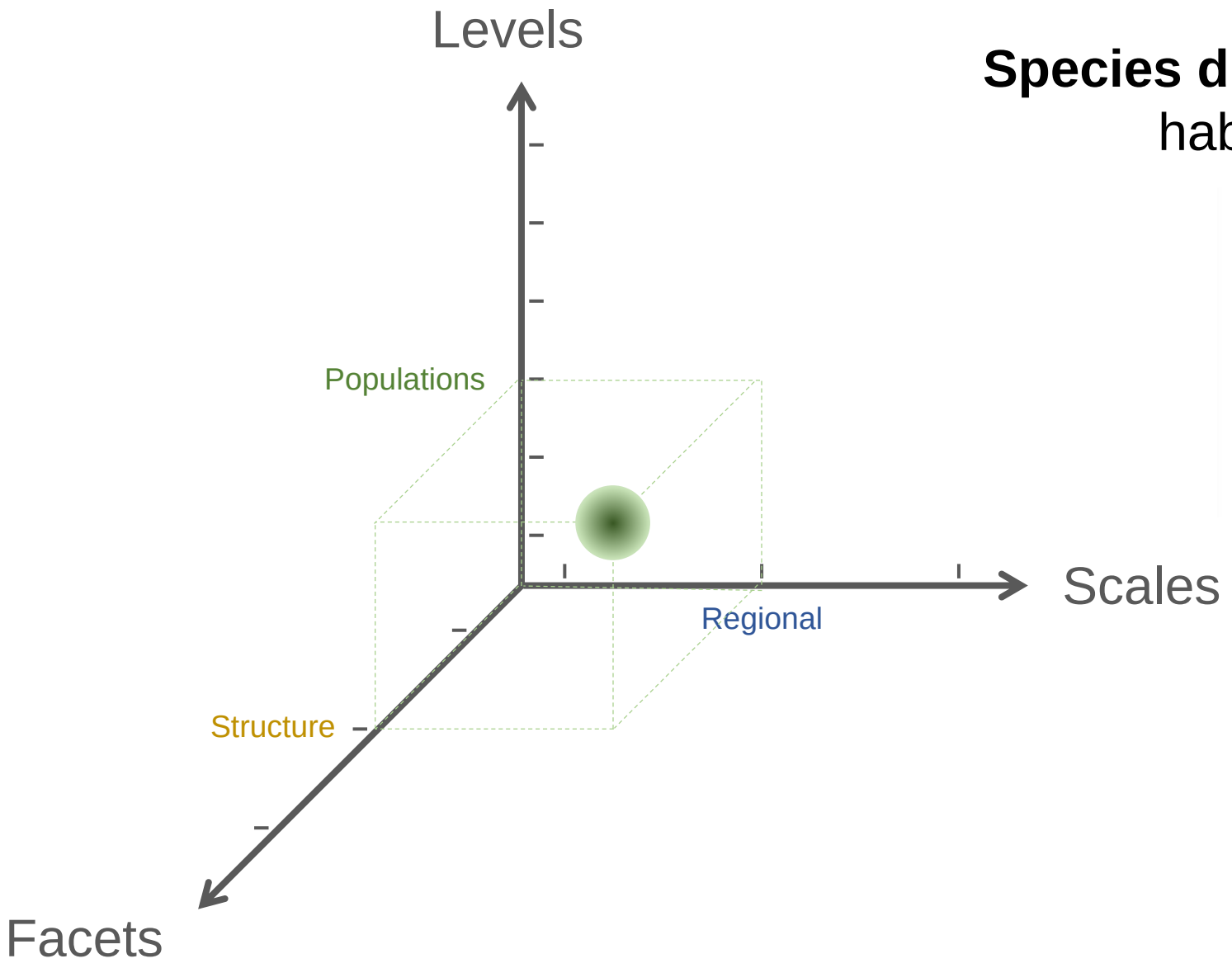
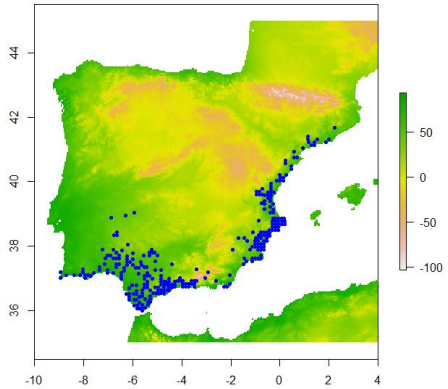


Species distribution or habitat suitability



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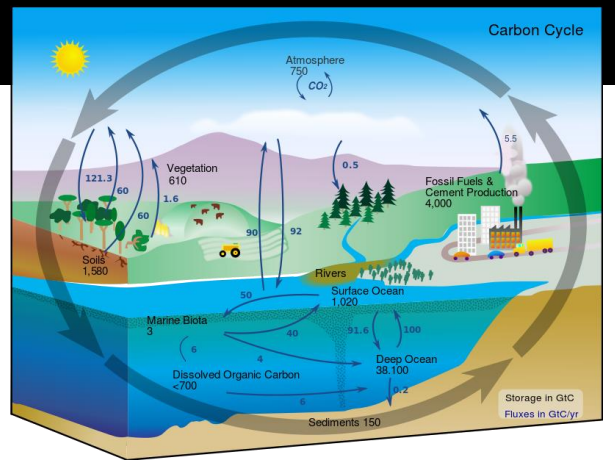
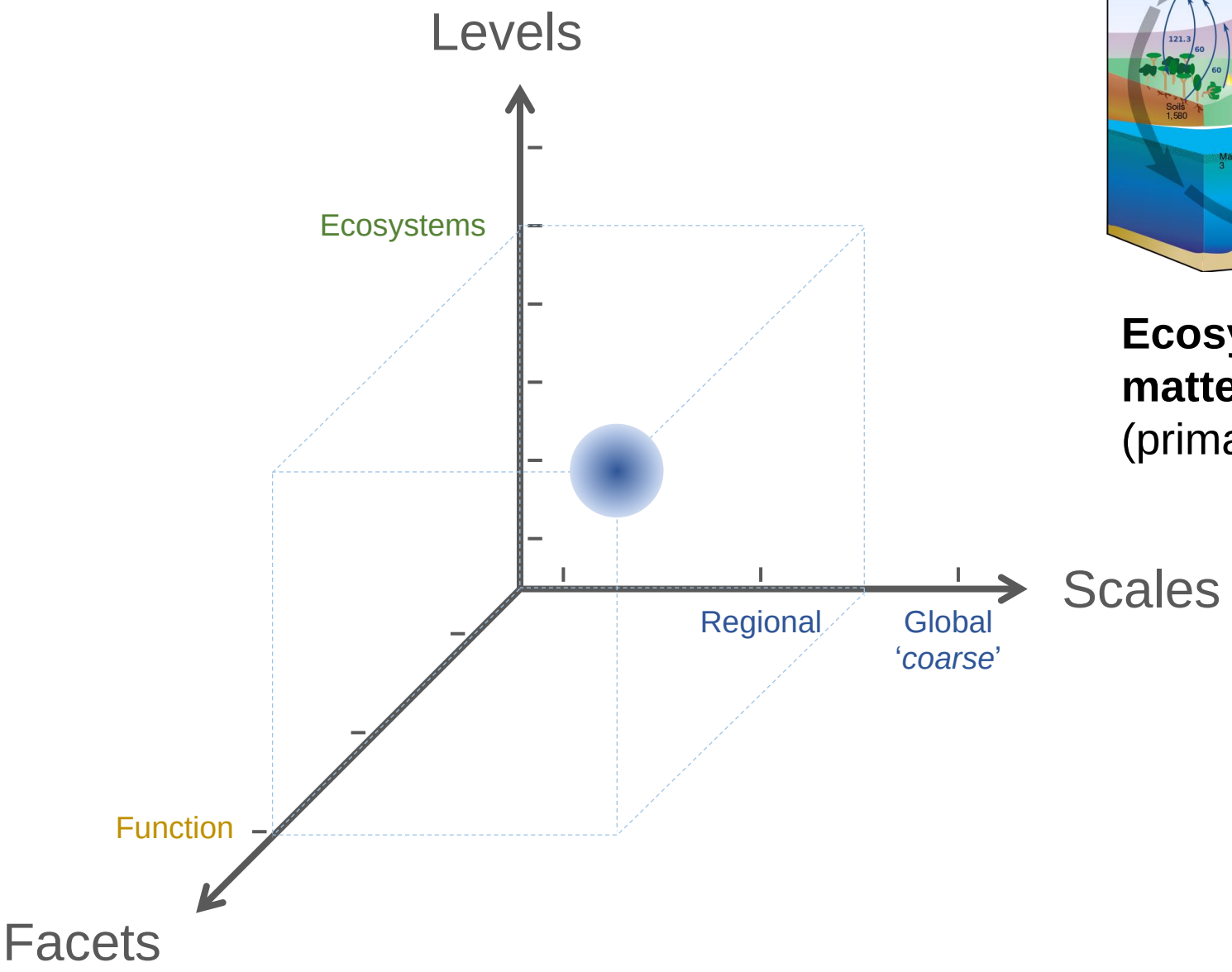
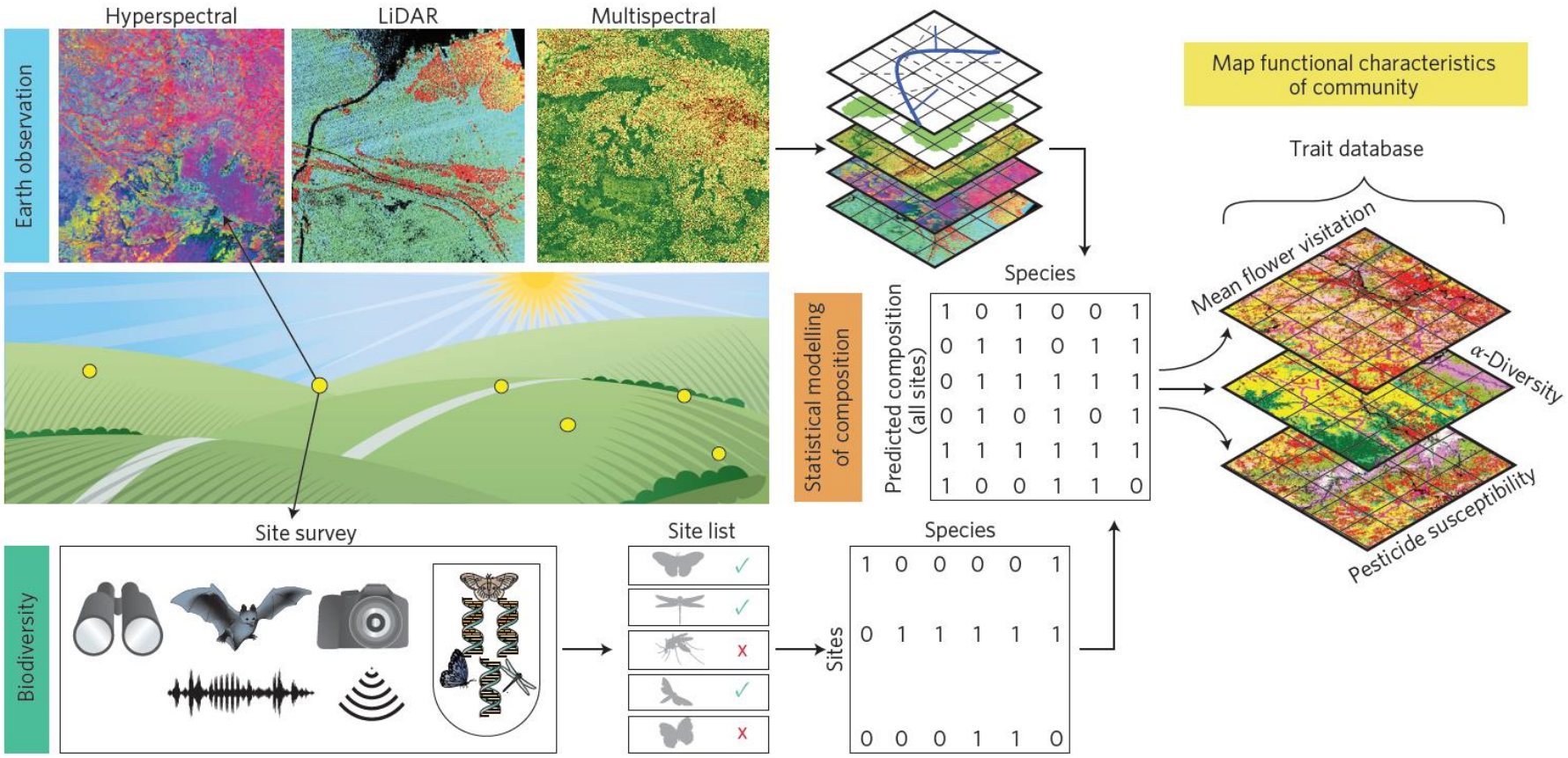


Ecosystem flows of matter and energy (primary production)



BIODIVERSITY ASSESSMENT AND MONITORING

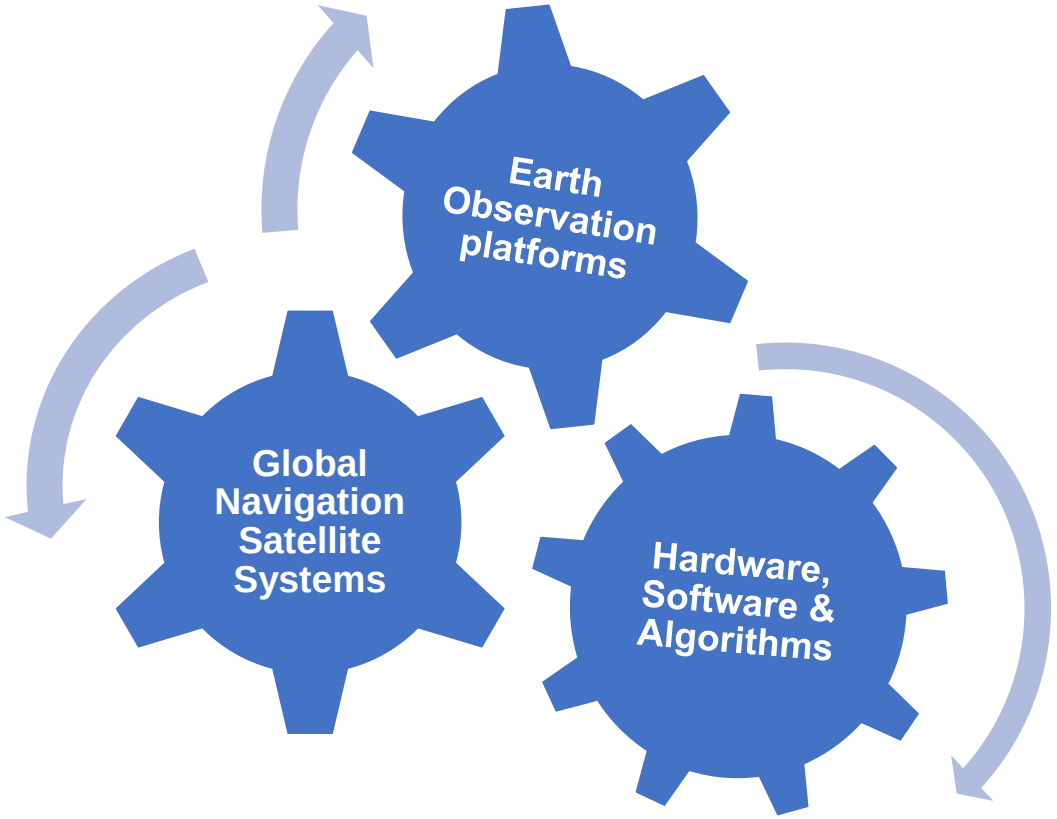
In all its complexity, **monitoring and assessing biodiversity status and change** requires appropriate **integrative approaches**

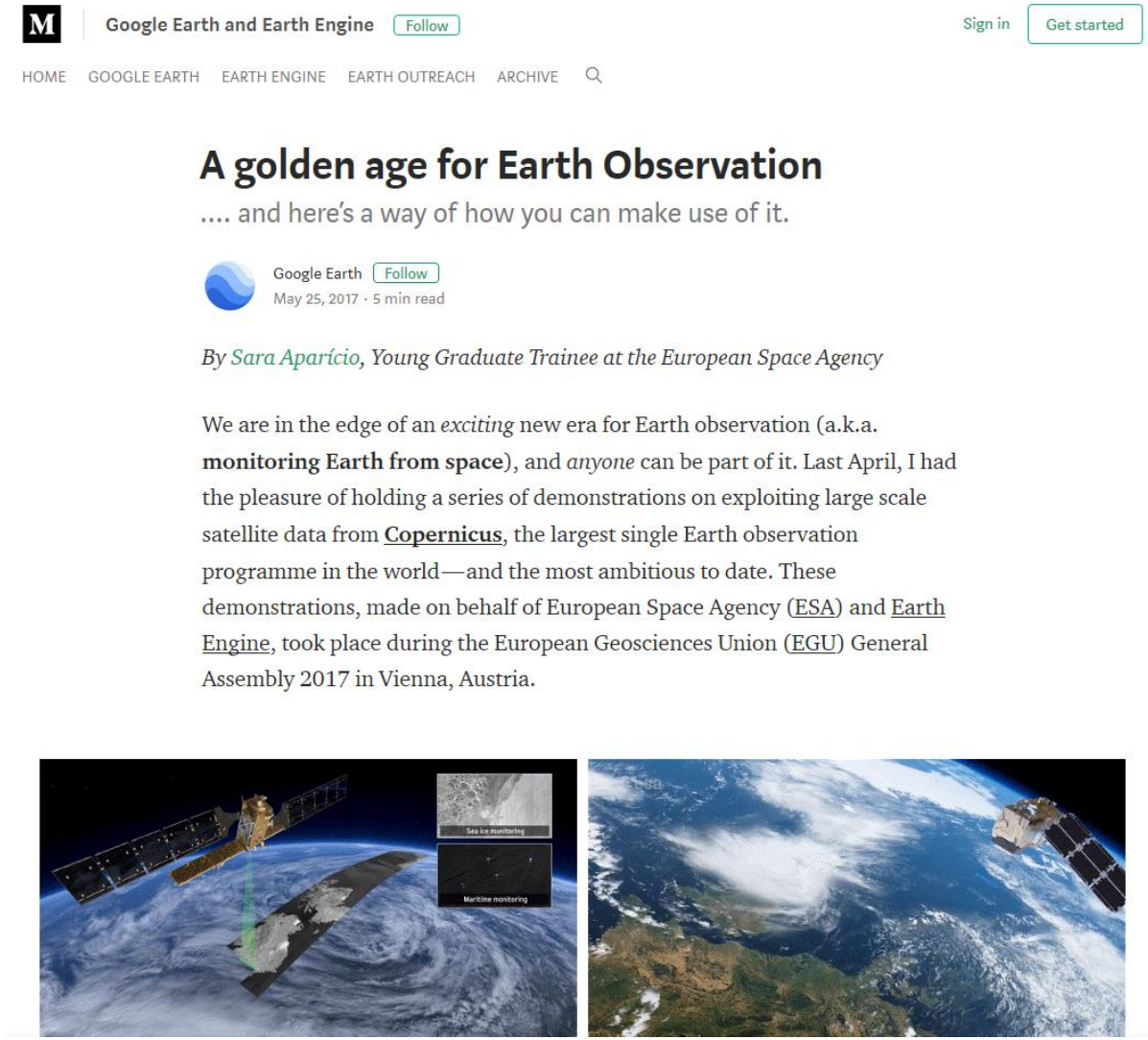


Bush et al., 2007. Nature Ecology & Evolution, 1:0176

THE "GOLDEN AGE" OF GEOINFORMATION AND SATELLITE EARTH OBSERVATION

Three main contributing factors for the expansion of GeoInfo and SatEO:





Google Earth and Earth Engine Follow

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HOME GOOGLE EARTH EARTH ENGINE EARTH OUTREACH ARCHIVE

A golden age for Earth Observation

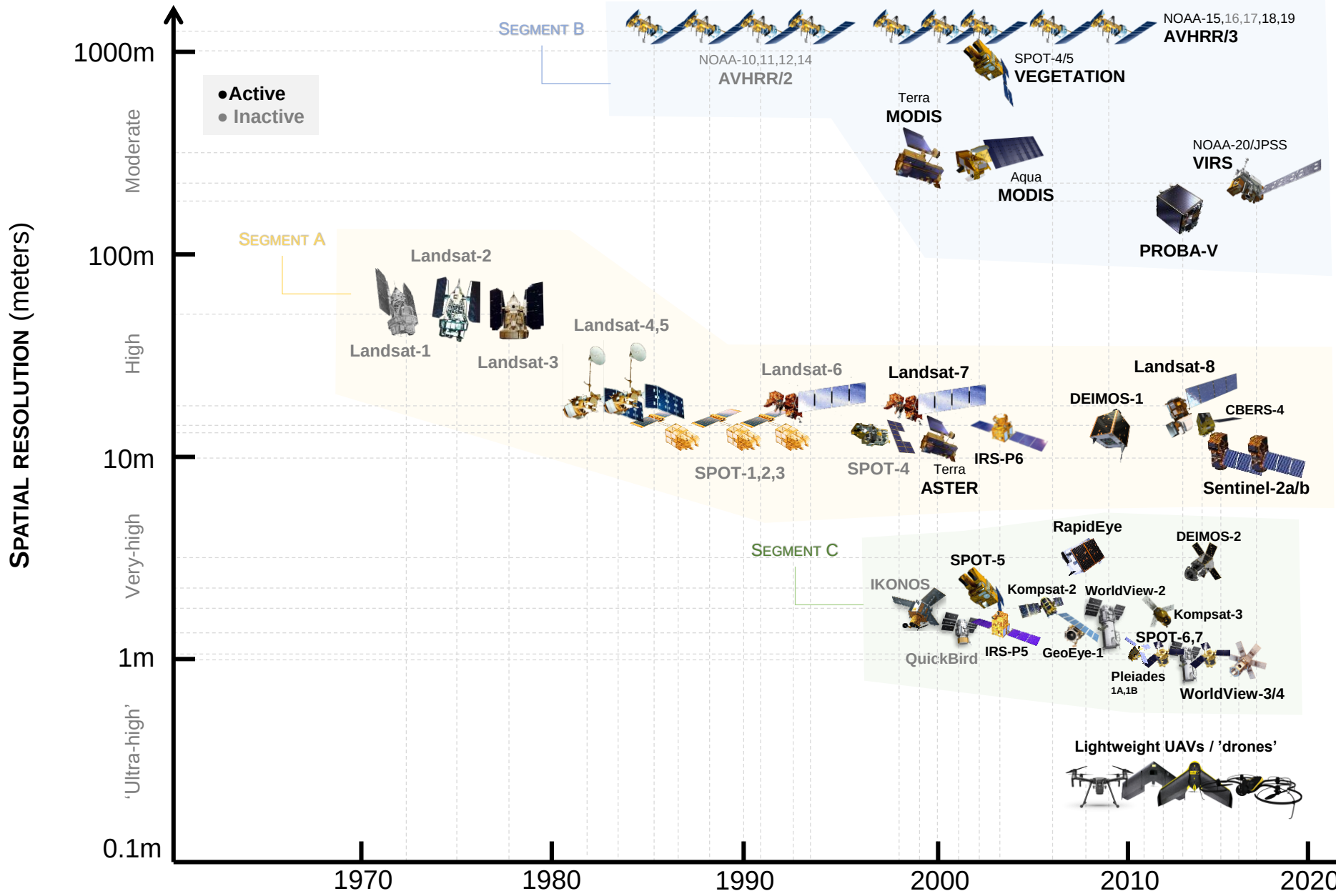
.... and here's a way of how you can make use of it.

Google Earth Follow
May 25, 2017 · 5 min read

By Sara Aparício, Young Graduate Trainee at the European Space Agency

We are in the edge of an *exciting* new era for Earth observation (a.k.a. **monitoring Earth from space**), and *anyone* can be part of it. Last April, I had the pleasure of holding a series of demonstrations on exploiting large scale satellite data from **Copernicus**, the largest single Earth observation programme in the world—and the most ambitious to date. These demonstrations, made on behalf of European Space Agency (ESA) and Earth Engine, took place during the European Geosciences Union (EGU) General Assembly 2017 in Vienna, Austria.

A BRIEF HISTORY OF EO OPTICAL SPACEBORNE PLATFORMS



Three main EO segments in environmental applications

SEGMENT A
- Starting in the 1970's
- High spatial resolution (10m-30m)
- Moderate temporal resolution (5-16 days)

SEGMENT B
- Starting in the 1980's
- Moderate spatial resolution(200m-1000m)
- High temporal resolution (~1 day)

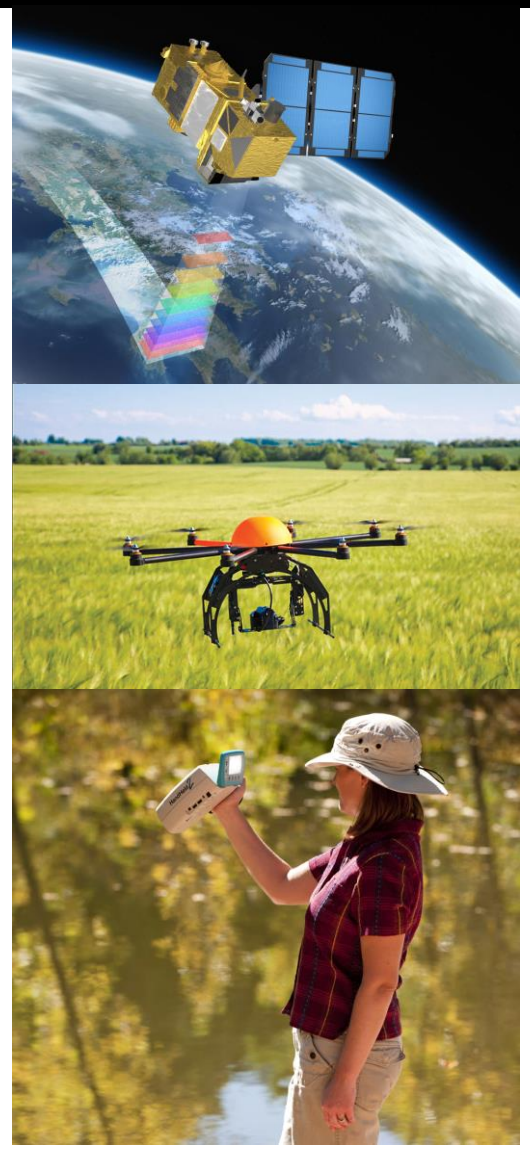
SEGMENT C
- Starting in the 2000's
- Very-high spatial resolution (1m-5m)
- Low temporal resolution (1-20 days)

WHAT IS REMOTE SENSING / EARTH OBSERVATION?

- Remote sensing (RS), also called Earth Observation (EO), *"is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information"*

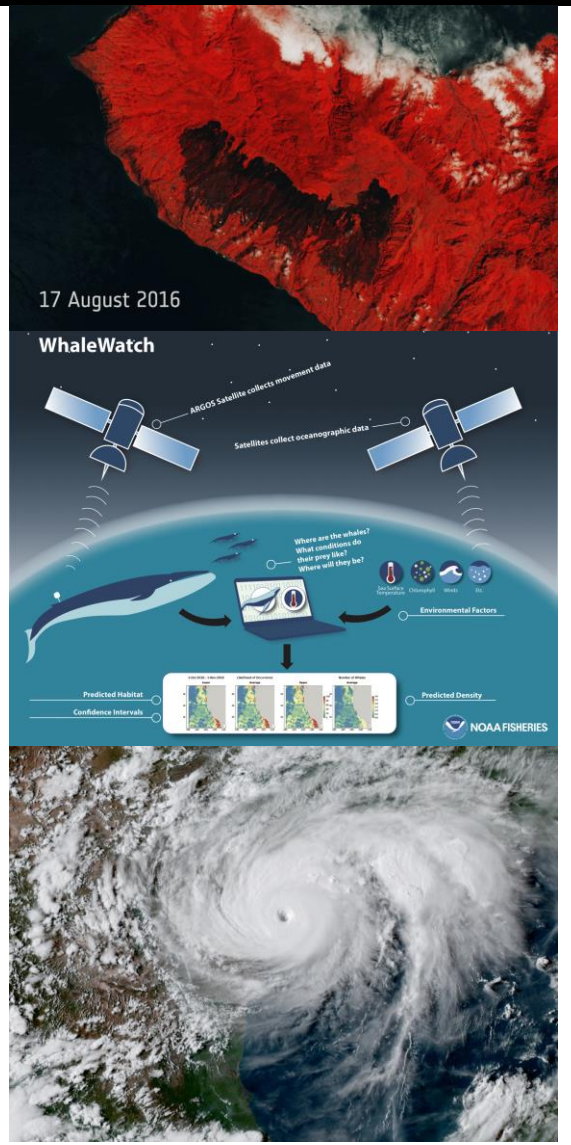
- RS/EO is a **multidisciplinary science** combining several different disciplines such as optics, spectroscopy, electronics and telecommunications, image processing, statistics, etc.

- Disciplines such as Landscape Ecology and Ecological Modelling strongly benefited from advances in Remote Sensing and Geographic Information Systems



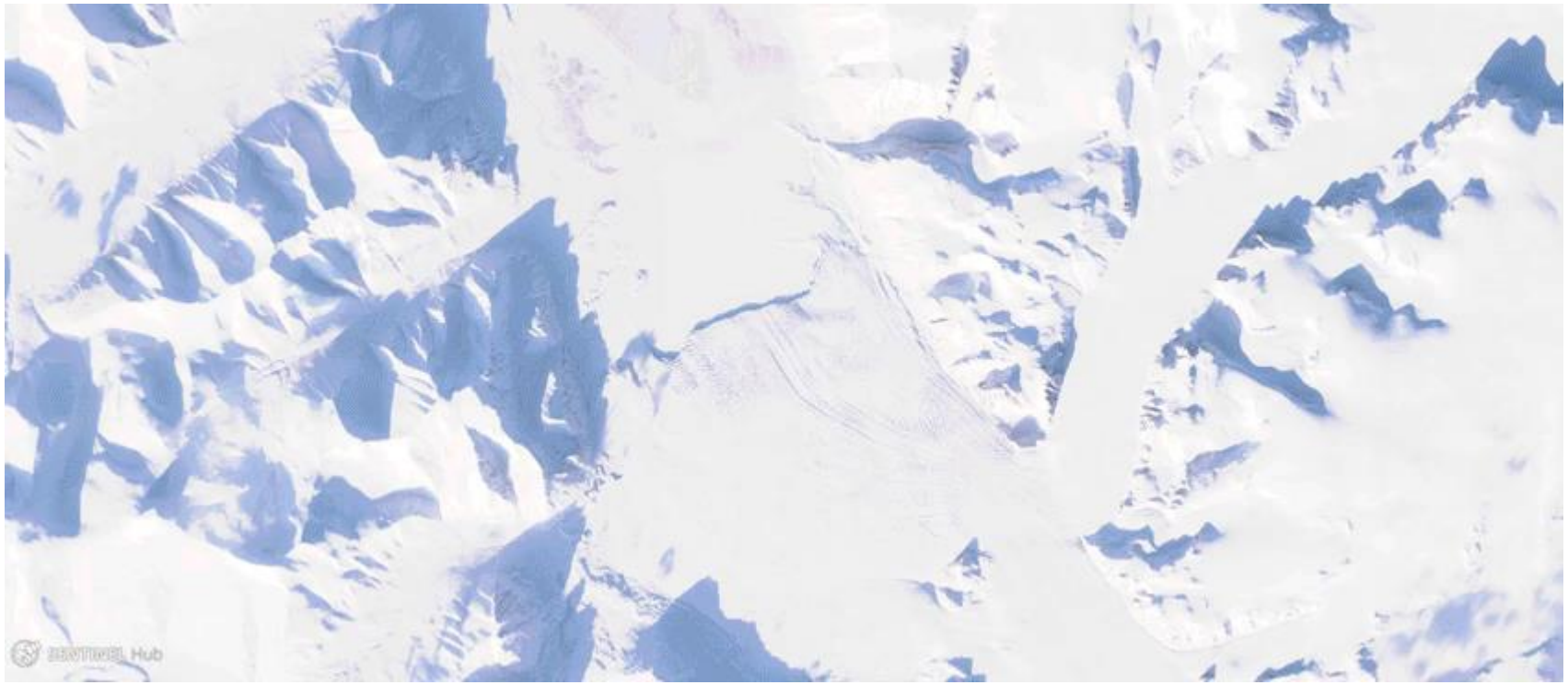
APPLICATIONS OF REMOTE SENSING / EARTH OBSERVATION

- Some examples by field:
  - **Biodiversity:** e.g., habitat mapping, non-native species monitoring, species distribution/habitat suitability modelling, species tracking
  - **Agriculture:** e.g., crop mapping and monitoring, precision farming
  - **Forestry**: e.g., deforestation rates, forest fire hazard and damage assessment, forest structure and composition, forest ‘health’
  - **Weather/climate**: e.g., weather forecasting and monitoring, extreme events (storms, flooding, hurricanes)
  - **Across fields**: land cover/land use and vegetation mapping and change assessment, disturbance monitoring, risk assessment



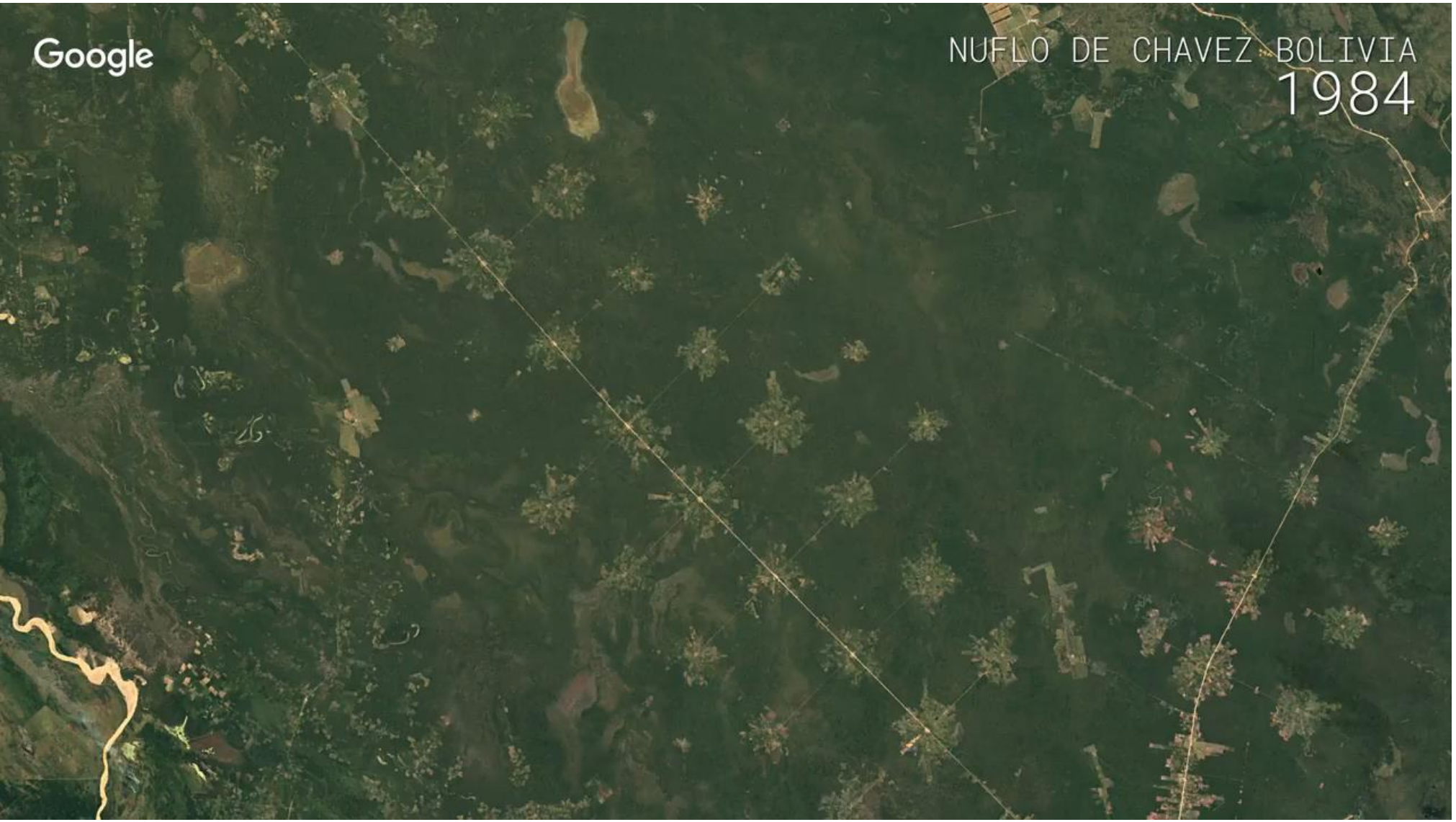
Aral Sea (Cazaquistan, Uzbequistan, Central Asia)

Este já foi o quarto maior lago do mundo com 68000 km² de superfície e 1100 km³ de volume de água, mas tem encolhido gradualmente desde os anos 1960 após projetos de irrigação soviéticos terem desviado os rios que o



Glaciar Mittag-Lefflerbreen em Spitsbergen, Svalbard (Finland)
2016 (natural color)

Satélite: ESA Sentinel-2



Nuflo de Chavez, Bolivia (Tropical forest in Amazonia)

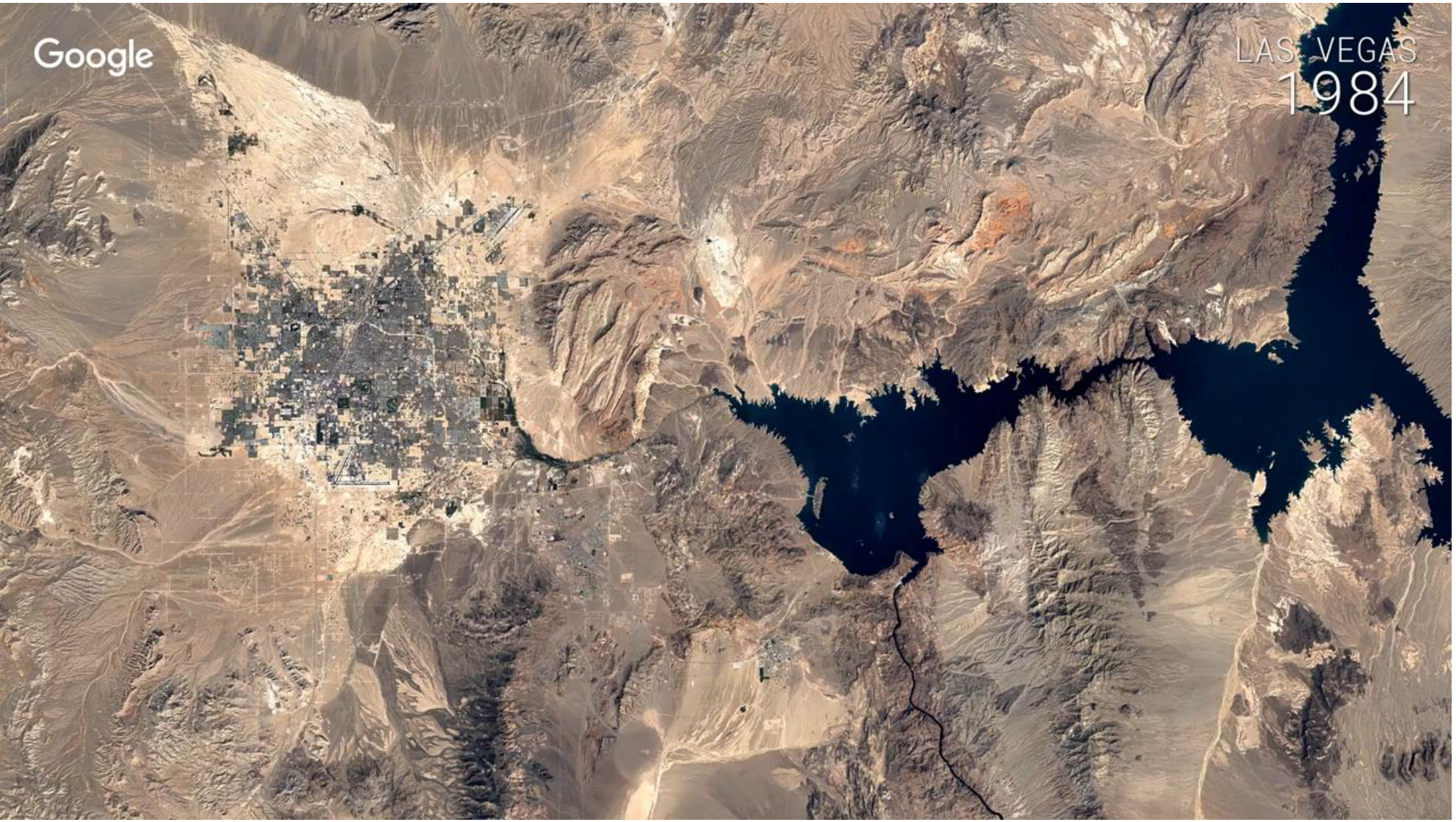
Deforestation

Satellite: Landsat/Sentinel-2

Bacia do Rio Guadalquivir
(Espanha), 2016

Ciclo anual de produção agrícola. com um diversificado conjunto de culturas: arroz, melancia, pimento, pepino, tomate e quinoa

Satélite: ESA Sentinel-2

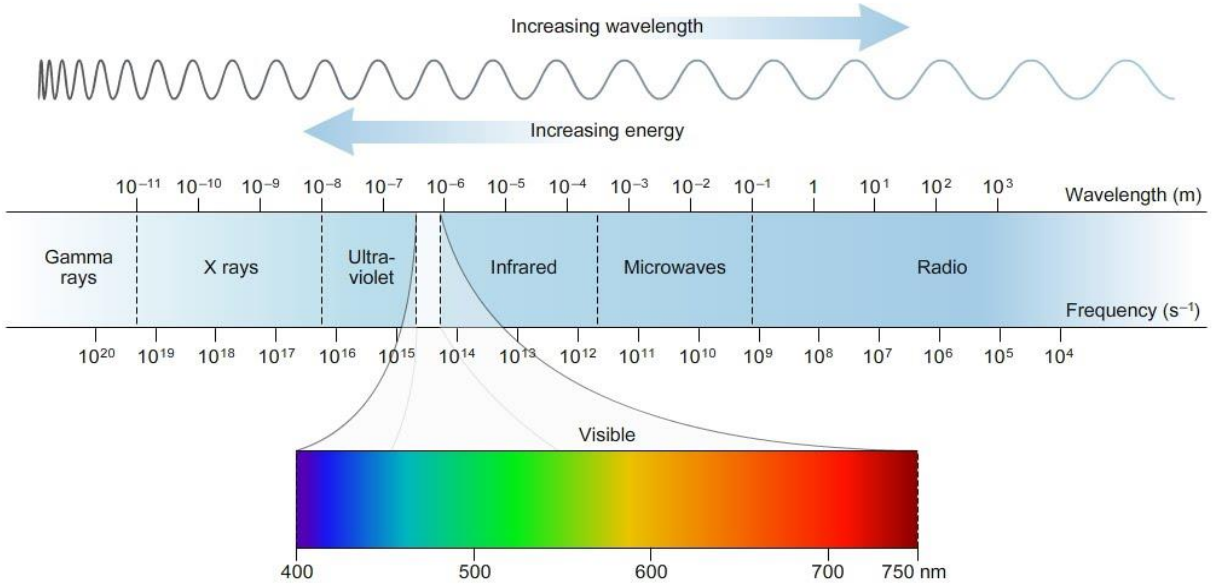


Las Vegas, EUA

Urbanização

Satélite:
Landsat/Sentinel-2

THE ELECTROMAGNETIC (EM) SPECTRUM



RS/EO allows to collect “images” in several portions of the EM spectrum which can be split up into several regions:

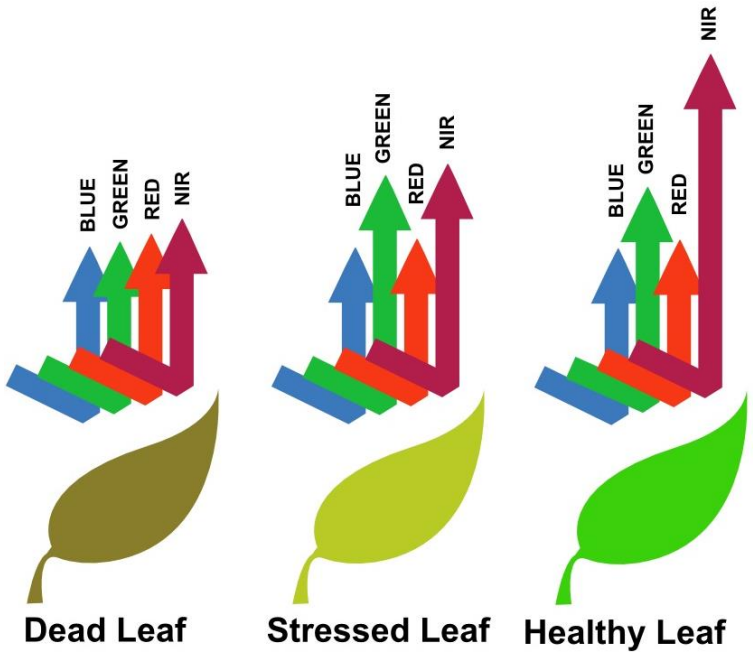
- **Visible** (400nm – 750nm)
- **Infrared** (750nm – 1mm)
- **Microwaves** (1mm – 1m)

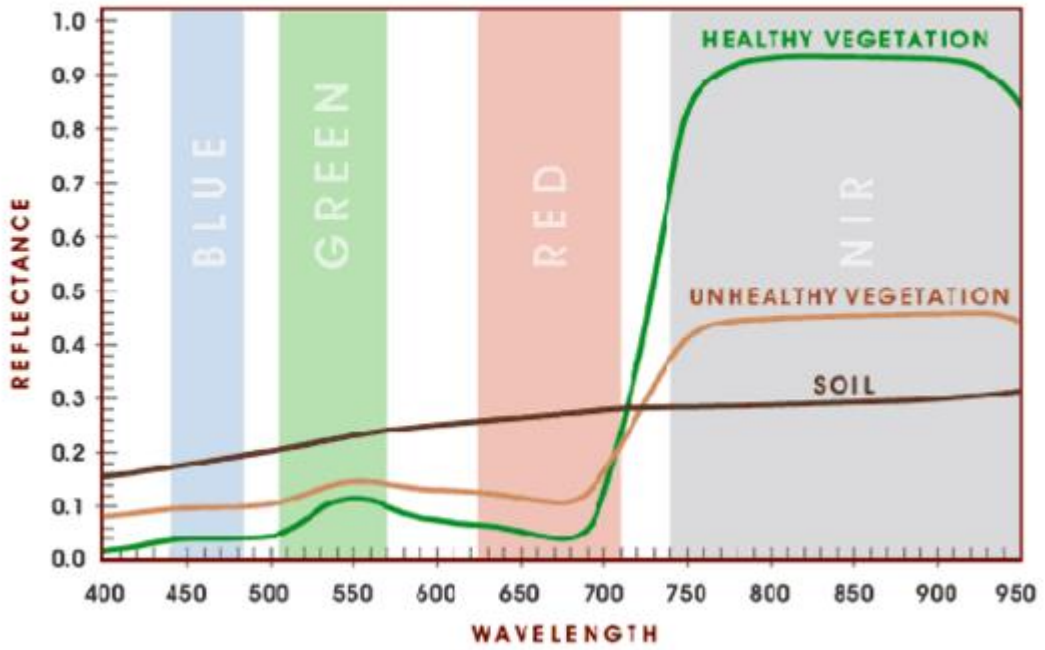
Optical remote sensing encompasses both the visible and the near/mid-infrared

Thermal remote sensing uses the far-infrared region for detecting emitted heat

Radar remote sensing uses EM radiation in the microwave spectrum

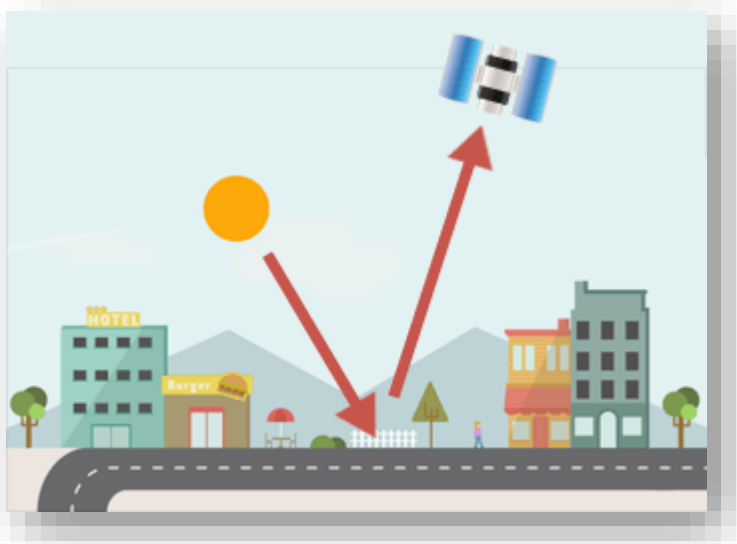
EM SPECTRUM AND VEGETATION STATUS





Active vs. passive sensors

Passive sensors



- Use the Sun as illumination source (i.e. radiation passing through the atmospheric window)
- Reflected radiation is captured by an airborne or orbiting sensor
- Limited by weather/cloud conditions

Active sensors

- Sensors with their own source of illumination
- The platform emits and receives radiation
- Can operate night/day and is not affected by climatic conditions

ACTIVE VS PASSIVE SENSORS – *MINI-QUIZZ*

- What kind of sensor is this camera: active or passive?

- What about if we turn the flash on?

TYPES OF RS PLATFORMS

- A RS platform is composed by a **carrying agent** (e.g., satellite) and the **sensor**

Some examples by type:

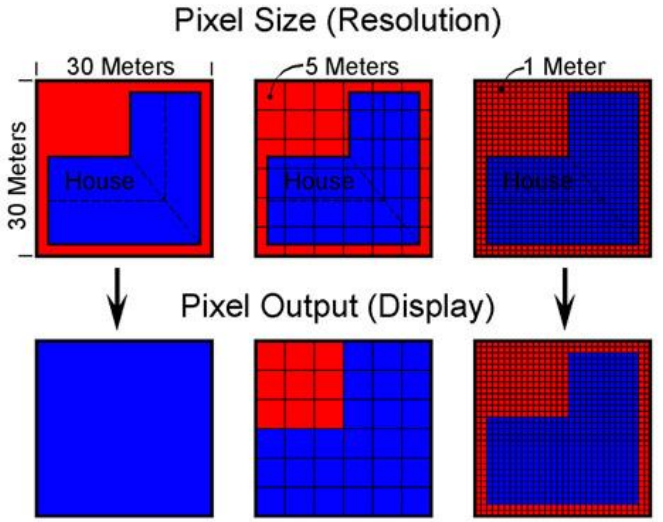
- **Proximal/ground-based**: field spectroradiometers, towers, portable masts, mobile hydraulic platforms

- **Airborne**: aircrafts and unmanned aerial vehicles (UAV)

- **Space-borne**: EO satellites

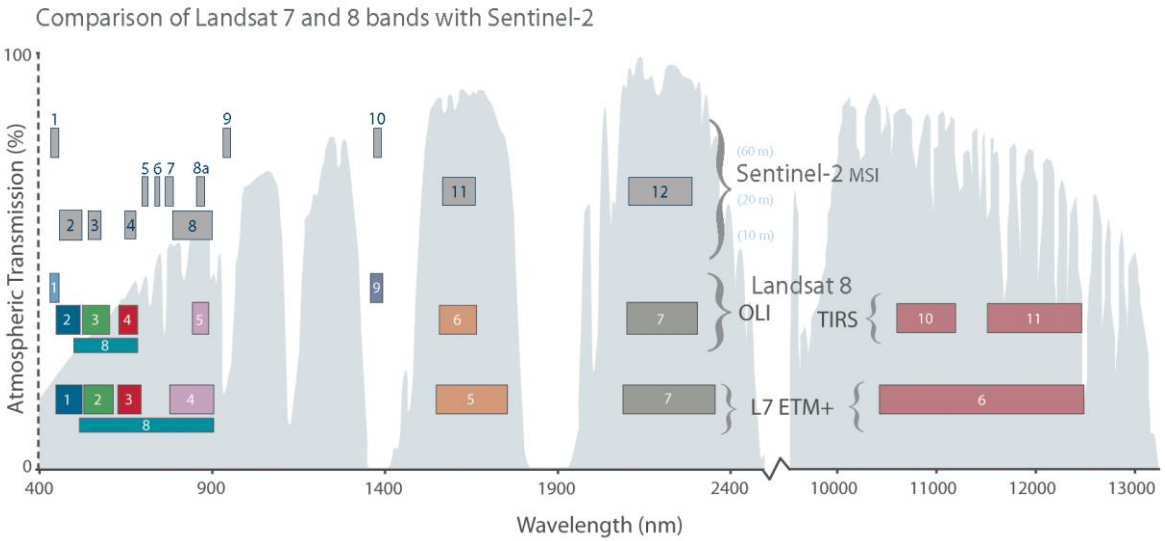
SELECTING THE APPROPRIATE SENSOR/PLATFORM – SPATIAL RESOLUTION

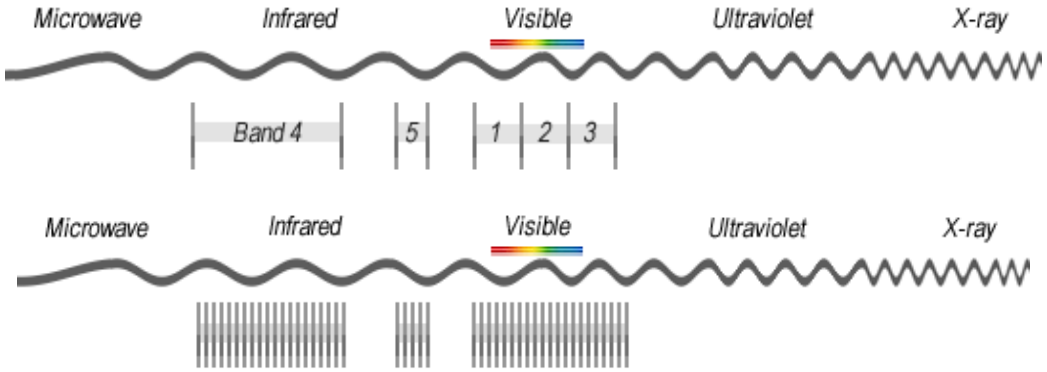
- *Spatial resolution* can be defined as the size of the smallest object that can be recognized in an image
- In image terms it is typically defined as the *pixel size*
- Spatial resolution is a key aspect of a sensor impacting the ability to map certain features
- According to spatial resolution, RS platforms and their data can be categorized as:
  - **Low** (>1000m)
  - **Moderate** (30-1000m)
  - **High** (5-30m)
  - **Very-high** (1-5m)
  - '**Ultra-high**' (<1m)



SELECTING THE APPROPRIATE SENSOR/PLATFORM – SPECTRAL RESOLUTION

- *Spectral resolution* can be defined by the number of regions of the EM spectrum that the sensor is capable of capturing
- In image terms is defined by the number of bands
- Sensors can be classified in two broad categories:
  - **Multispectral** (3-30 spectral bands)
  - **Hyperspectral** (>40 bands)



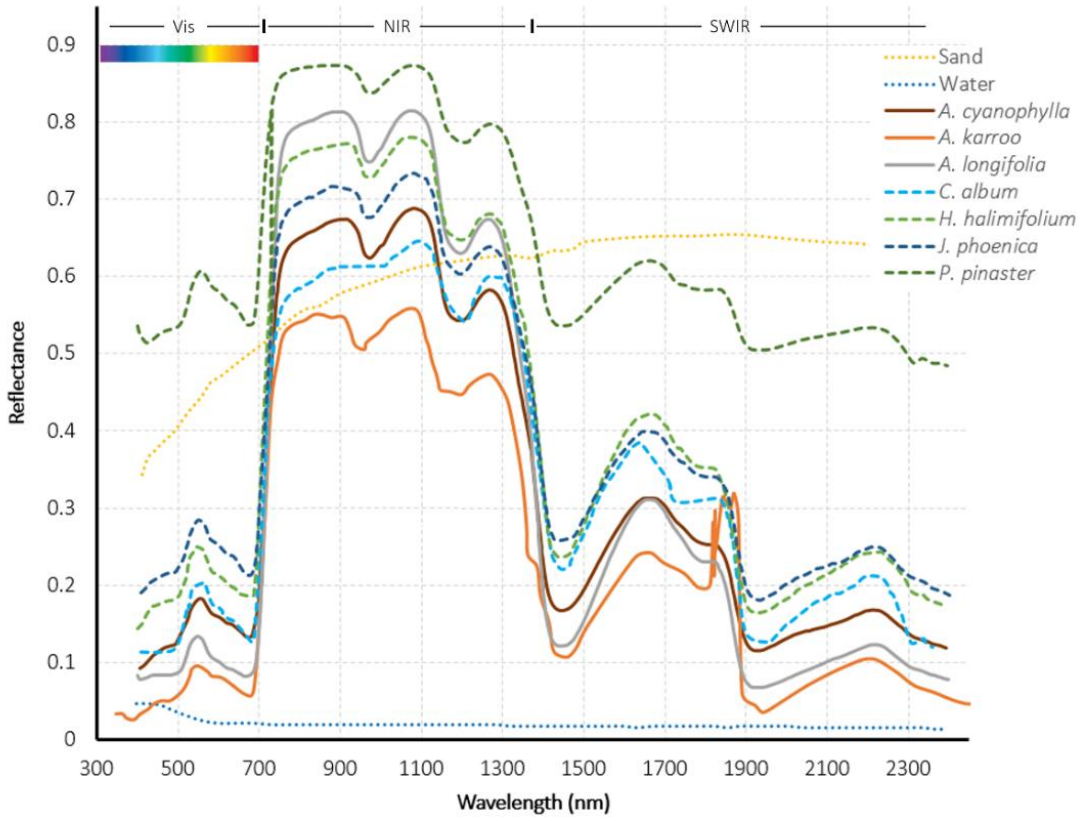


SPECTRAL RESOLUTION – *MINI-QUIZZ*

- How many bands does this camera have?

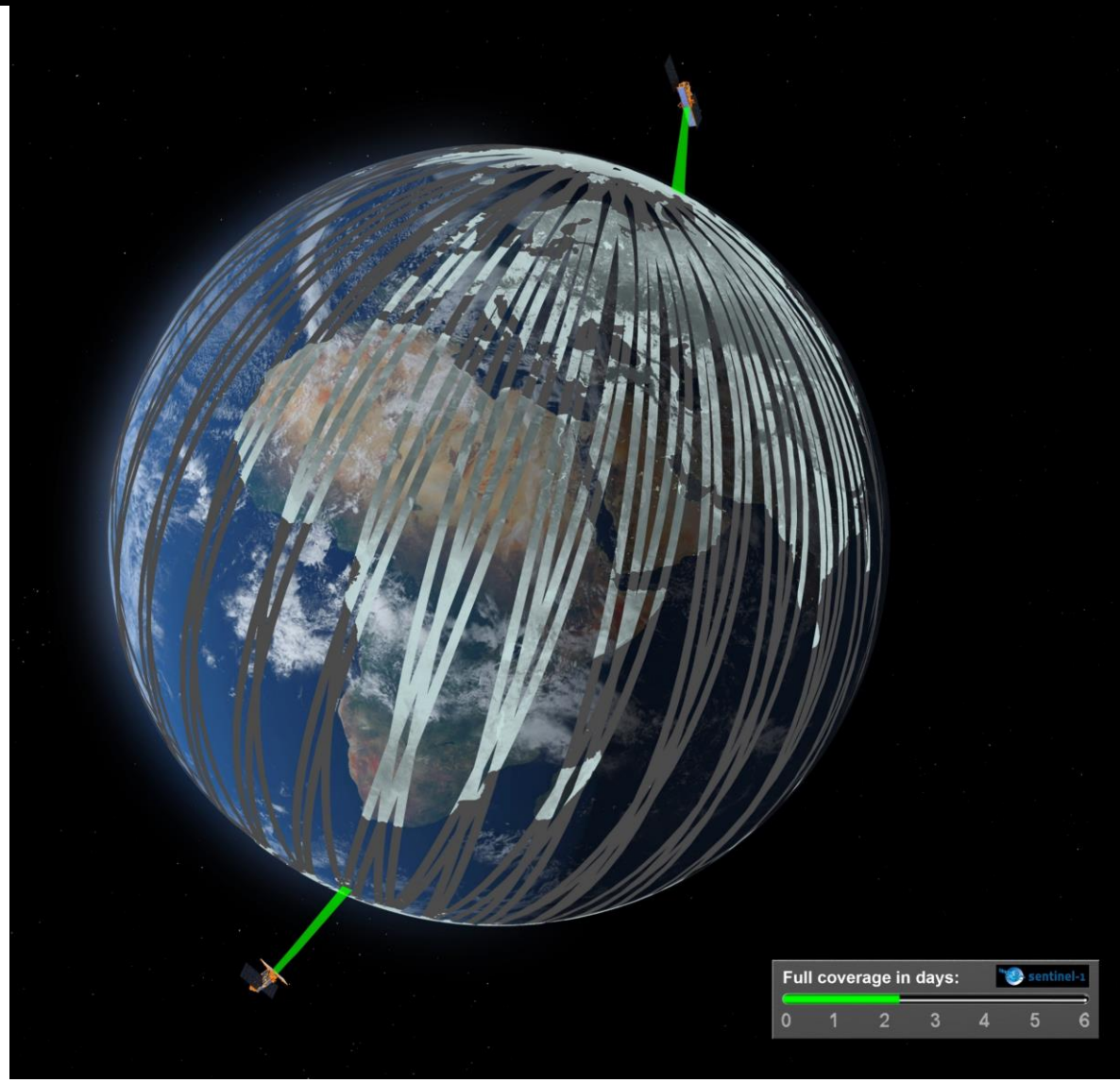
SELECTING THE APPROPRIATE SENSOR/PLATFORM – SPECTRAL RESOLUTION

- Multispectral sensors have a limited coverage of the EM spectrum targeting certain regions with varying wavelength intervals
- Hyperspectral sensors allow a continuous cover of the EM spectrum
- *Spectral resolution* strongly impacts the ability to discriminate different land cover types
- Especially important to identify (for example) different plant species



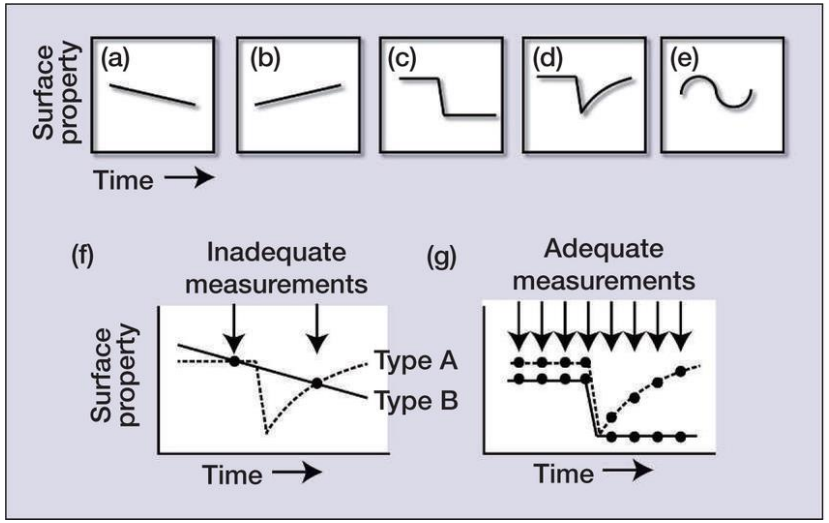
SELECTING THE APPROPRIATE SENSOR/PLATFORM – TEMPORAL RESOLUTION

- (For space-borne platforms) *temporal resolution* (related to *revisit time)*, is defined as the amount of time it takes for a satellite platform to return to collect data from exactly the same place on Earth
- Depends on orbital and sensor characteristics
- Temporal resolution is high when the revisiting time is low and vice-versa
- Usually expressed in hours or days

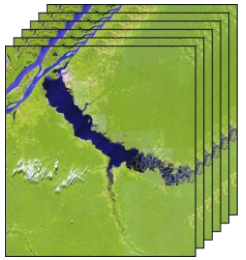


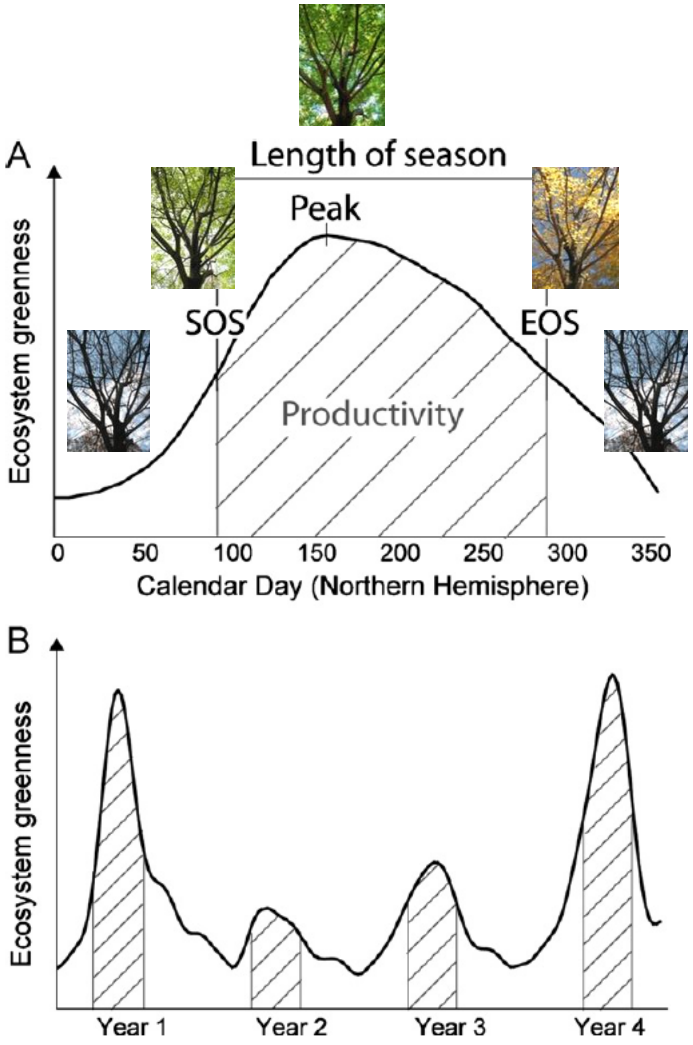
SELECTING THE APPROPRIATE SENSOR/PLATFORM – TEMPORAL RESOLUTION

- Temporal resolution is critical to **track changes** in Earth's surface

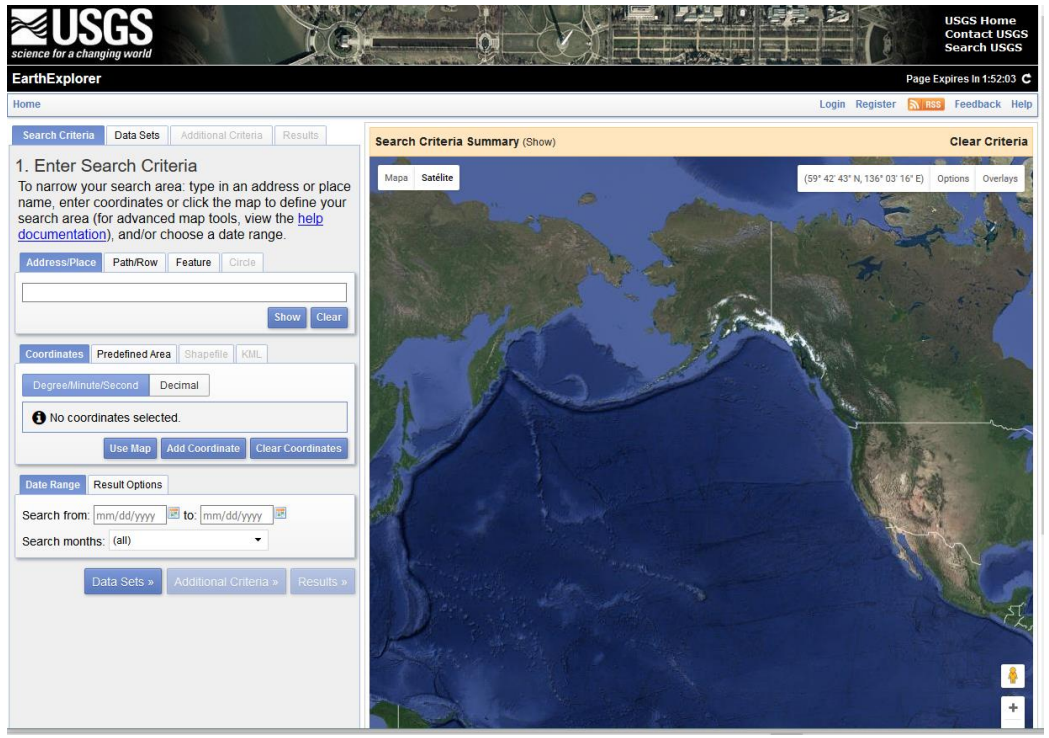


- High-temporal resolution RS platforms allow to stack multiple images to **assess intra-annual** (i.e., phenological) and **inter-annual changes** (e.g., disturbance, land cover change, replacement by non-native/invasive species)





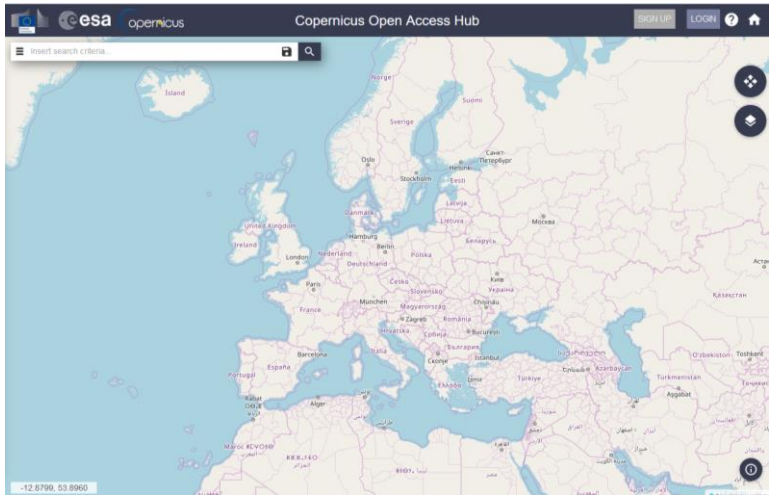
WHERE TO SEARCH AND DOWNLOAD SATELLITE IMAGE DATA? LANDSAT / MODIS



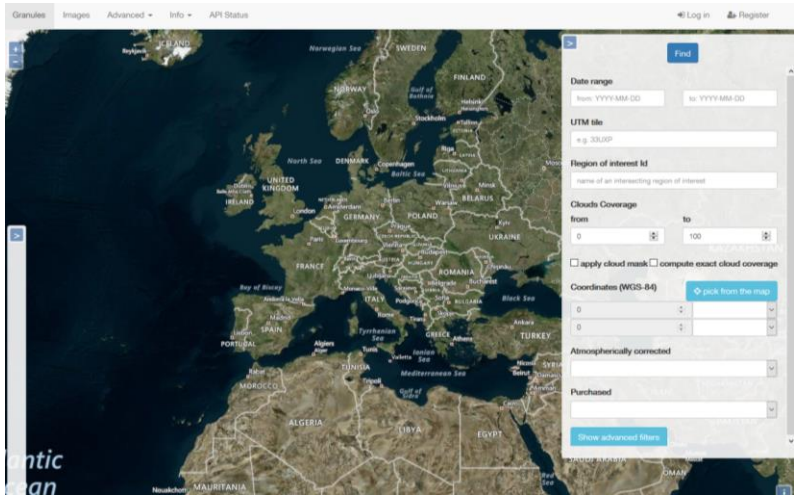
https://earthexplorer.usgs.gov/

https://espa.cr.usgs.gov/

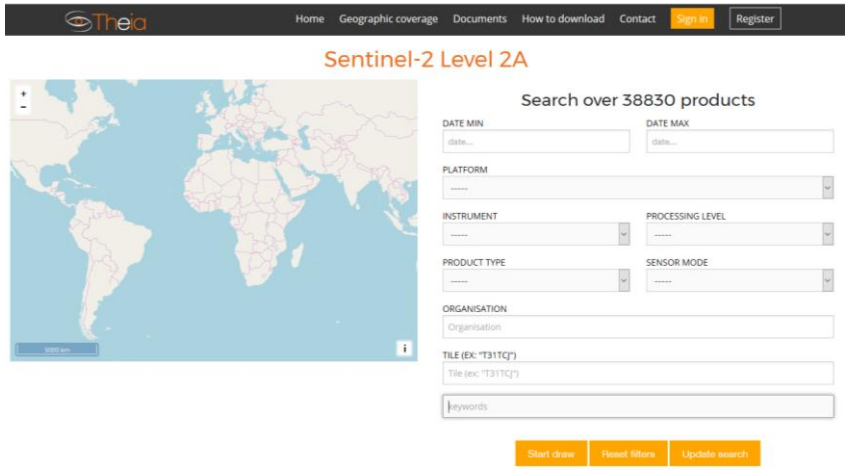
WHERE TO SEARCH AND DOWNLOAD SATELLITE IMAGE DATA? SENTINEL-2



https://scihub.copernicus.eu/dhus/#/home



https://s2.boku.eodc.eu



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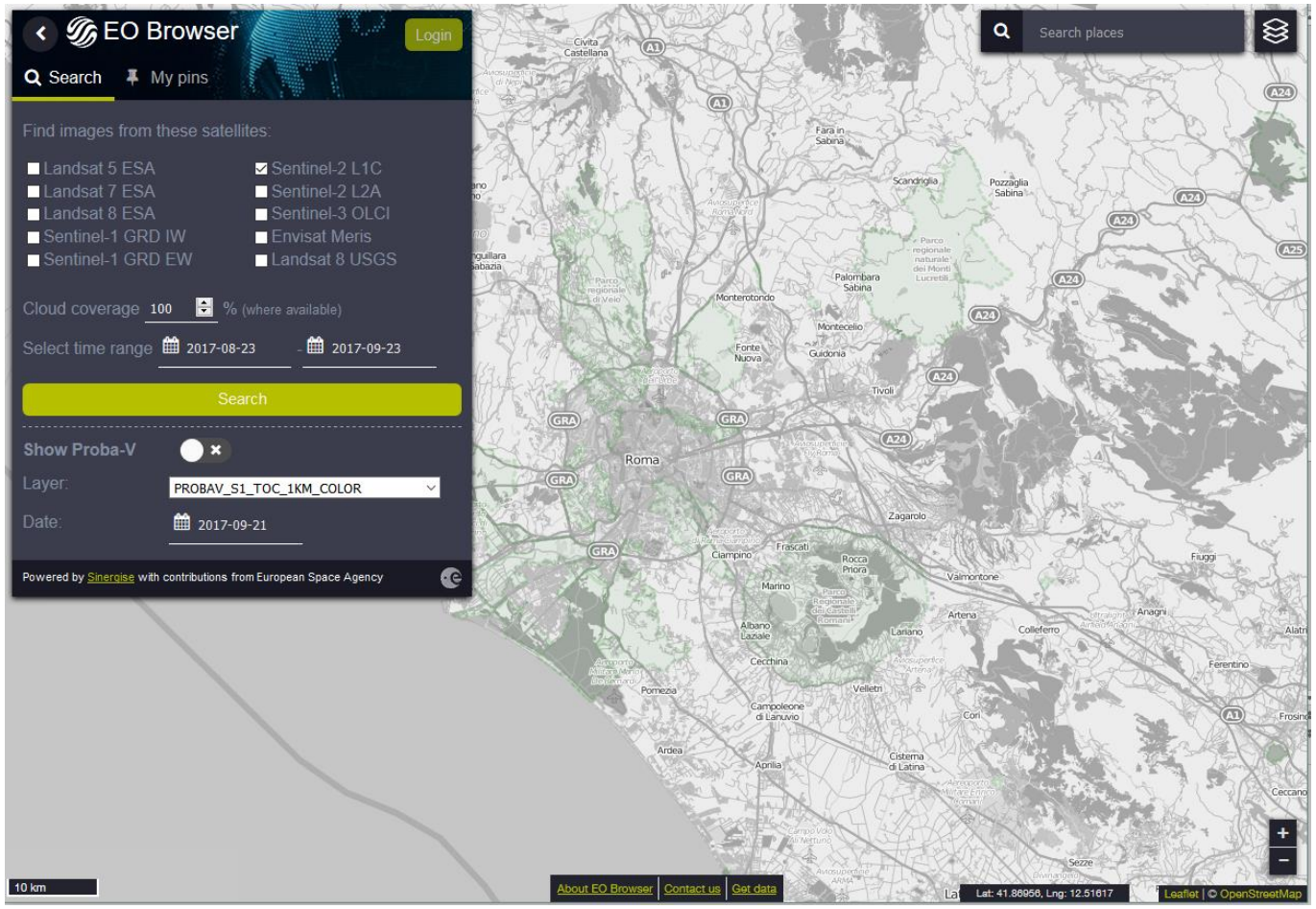
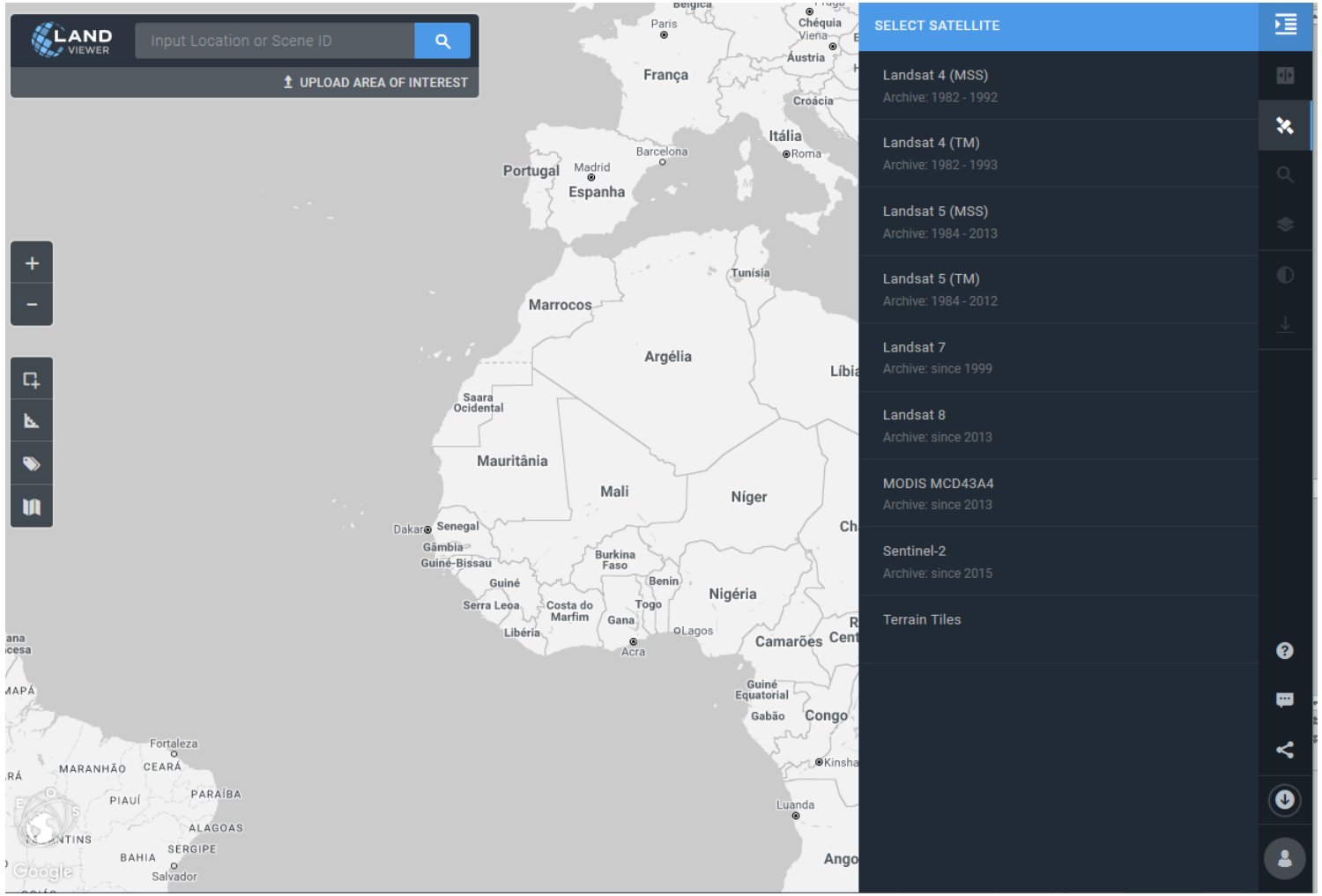
WHERE TO SEARCH AND DOWNLOAD SATELLITE IMAGE DATA?



http://apps.sentinel-hub.com/eo-browser

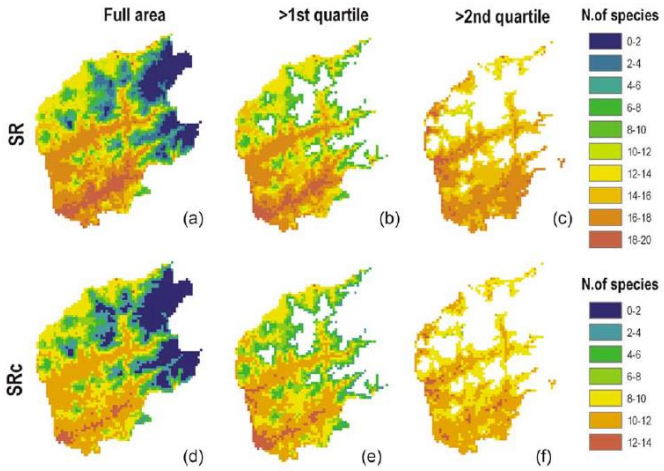
WHERE TO SEARCH AND DOWNLOAD SATELLITE IMAGE DATA?

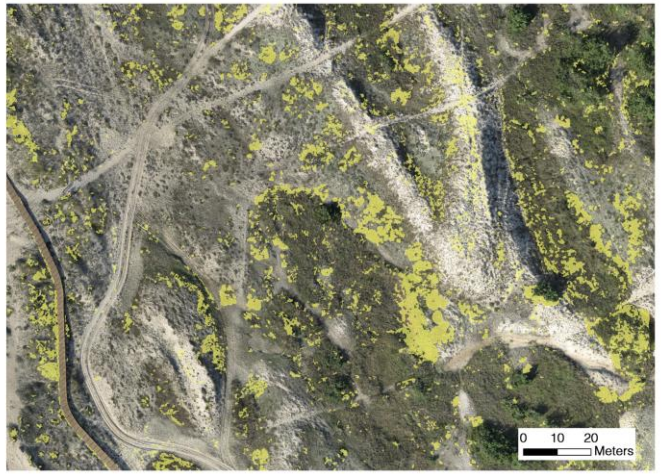


https://lv.eosda.com

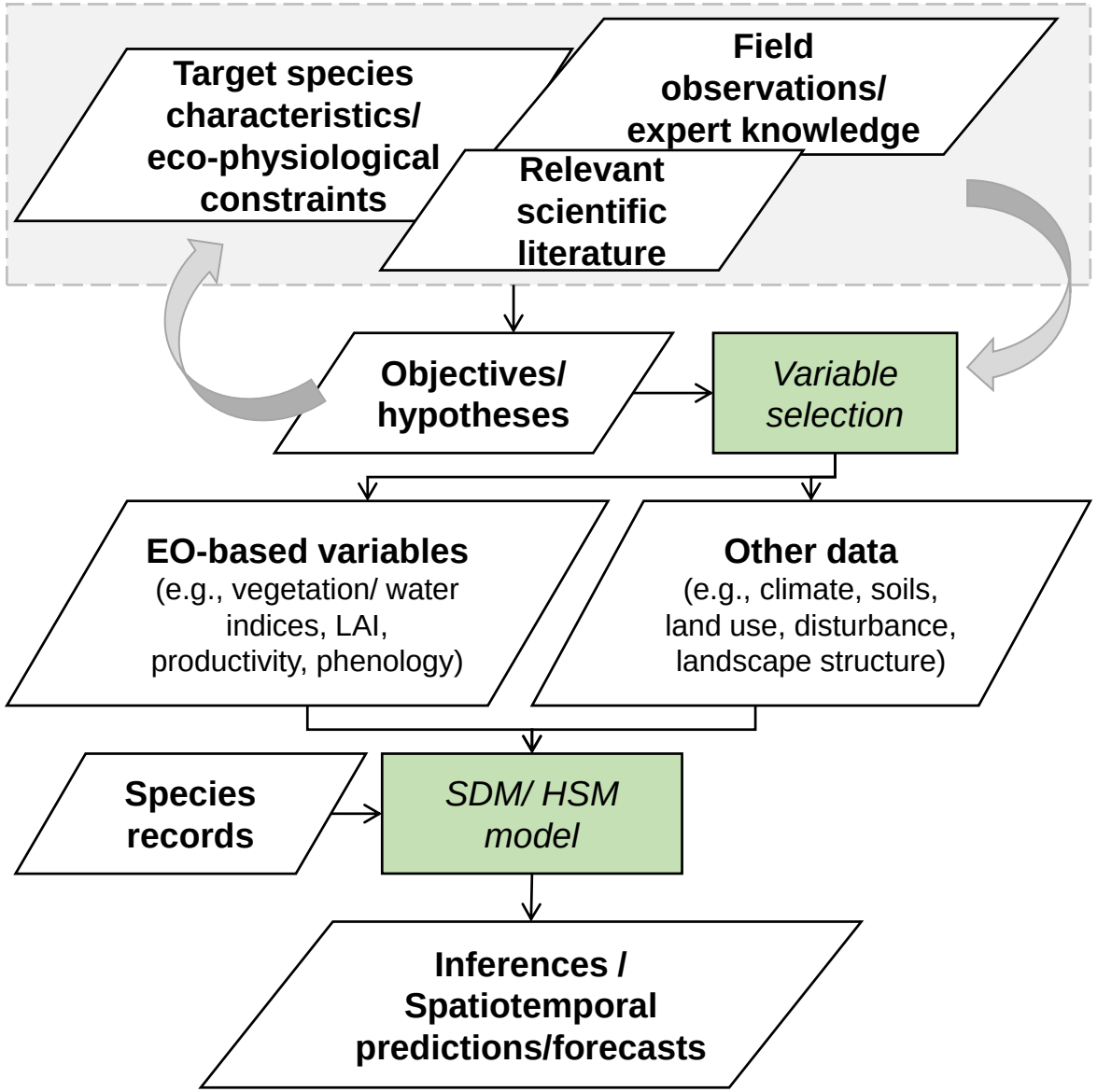
DETECTION/MAPPING VS. HABITAT SUITABILITY MODELLING

- RS/EO data is commonly used for mapping the distribution of non-native species
- Detecting/mapping the actual distribution or modelling the potential distribution/ habitat suitability?
- Be attentive to your **objectives and hypothesis**!
- Are variables related to the species distribution? How?
- **Scale** (grain size and extent) is crucial
- Pay attention to the **spatial resolution of RS/EO data** and species traits
- How do plant/crown size and other characteristics affect the signal?



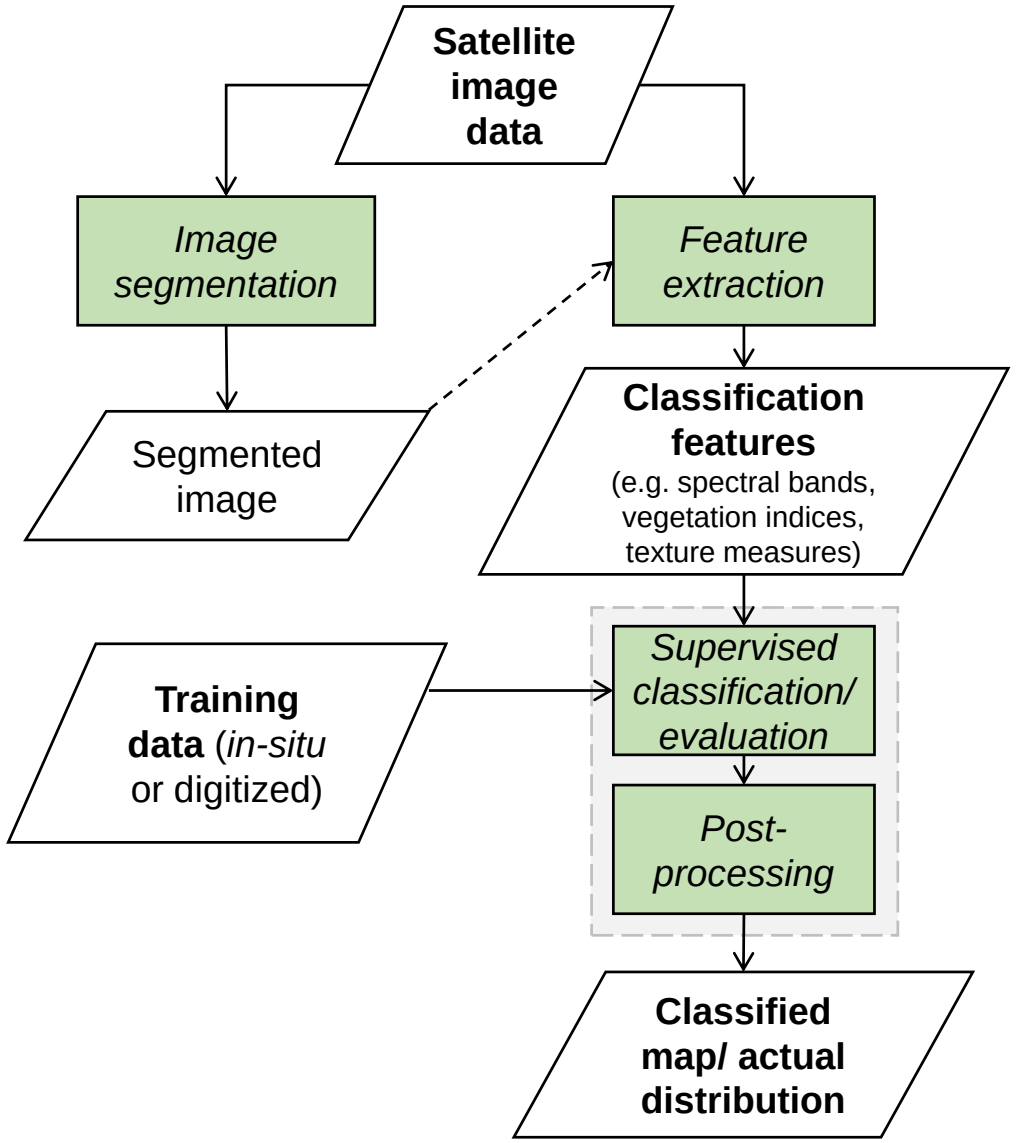


HABITAT SUITABILITY MODELLING OF A NON-NATIVE TREE SPECIES



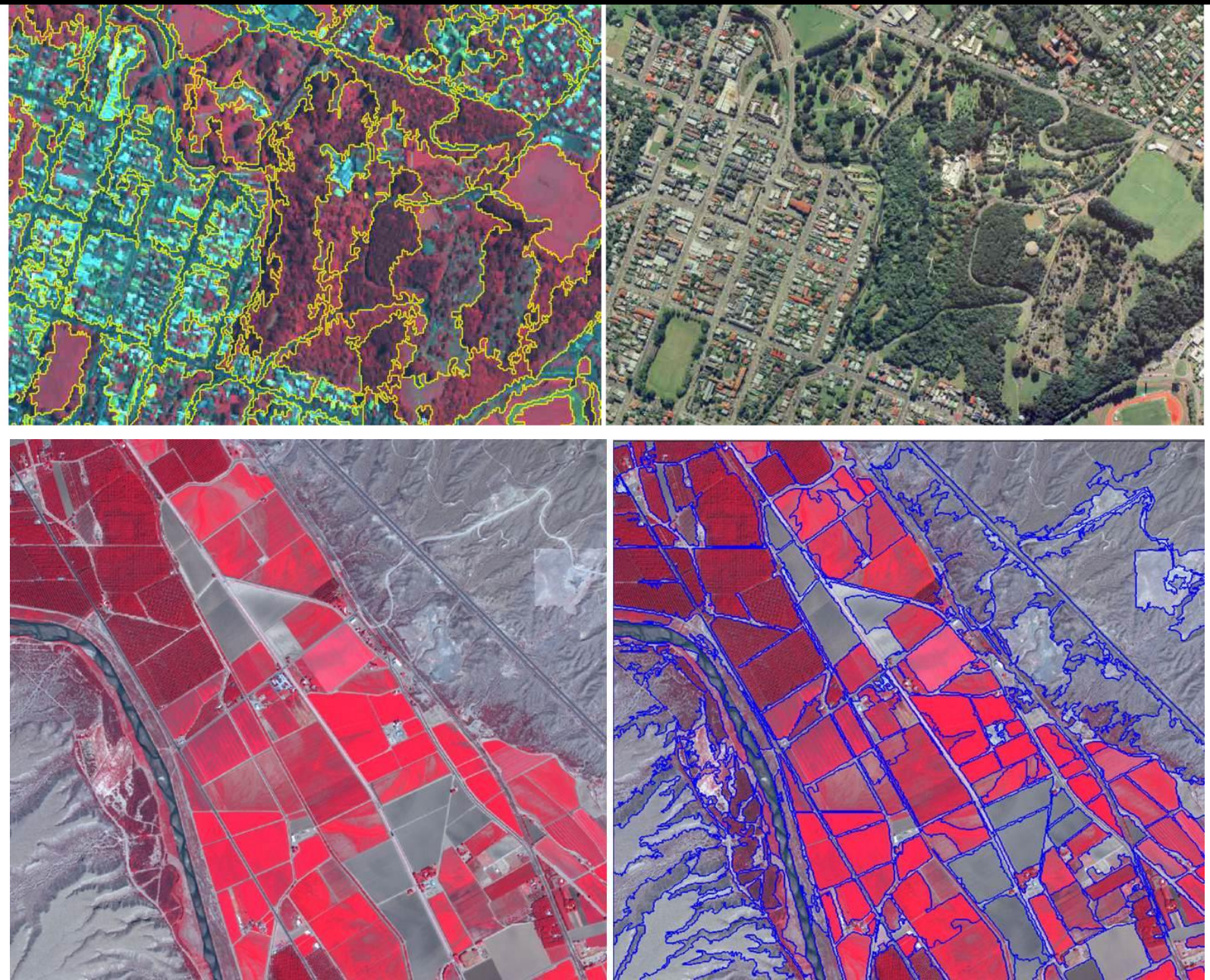
- **Emphasis is towards inference** on explanatory driving factors (and spatiotemporal prediction/ forecasting)
- Objectives and working hypothesis (should be) *a priori* defined
- Clear linkage between explanatory/predictive variables and the target species
- Usually employed at larger scales (i.e., larger extents and coarser grain)
- Typically, other variables (besides EO-based ones) will be used for modelling (e.g., bioclimatic variables, soil properties/type, topography, land use, disturbance, landscape structure)

MAPPING THE ACTUAL DISTRIBUTION OF A NON-NATIVE TREE SPECIES WITH EO DATA

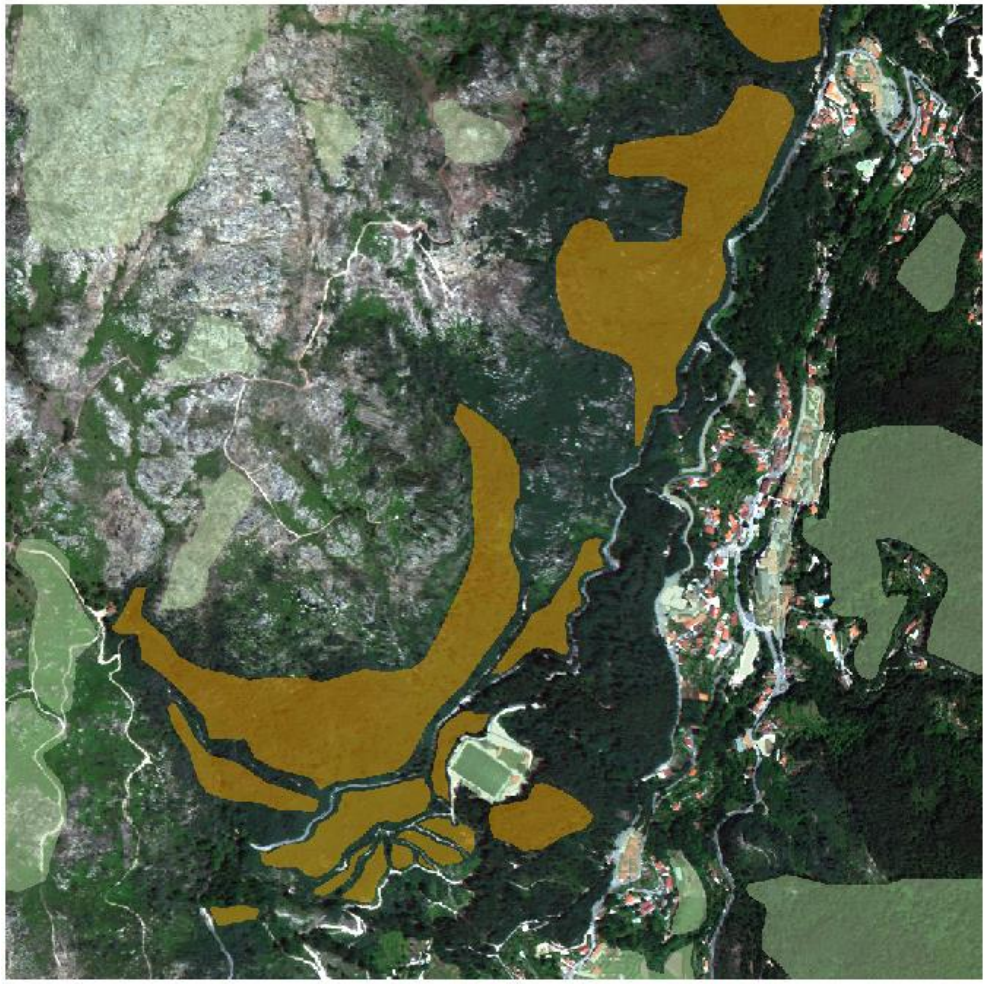


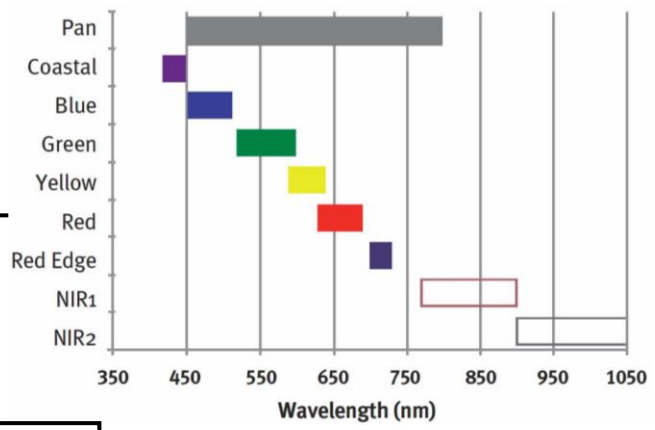
- Emphasis is towards **mapping/detecting the actual distribution** of the species in the landscape and not in investigating causal factors
- Monitoring changes in actual distribution
- Based on **spectral signatures** and classification rules/functions
- Imagery characteristics (spatial, spectral and temporal mainly) must allow to clearly discriminate the species
- Using ancillary data is less common (e.g., elevation, slope)
- For optical RS, understory tree species are not detectable (use SDM/HSMs in that case?)

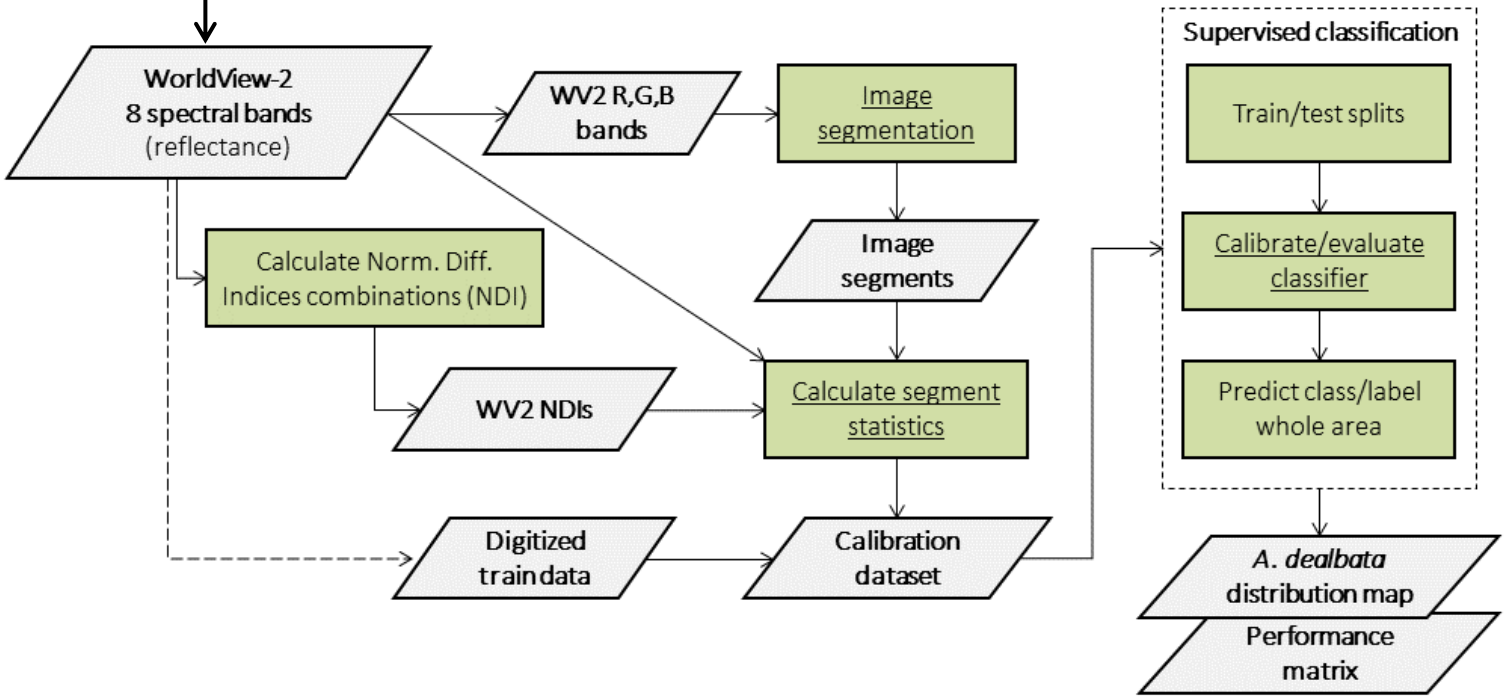
Image segmentation



MAPPING THE ACTUAL DISTRIBUTION OF A NON-NATIVE TREE SPECIES WITH EO DATA







SEGOPTIM PACKAGE – WHAT DO YOU NEED TO MAKE IT WORK

What you need:

Train data
(single-layer raster)

Segmentation features
(multi-layer raster)

Classification features
(multi-layer raster)

Control parameters

SegOptim
package

What you get:

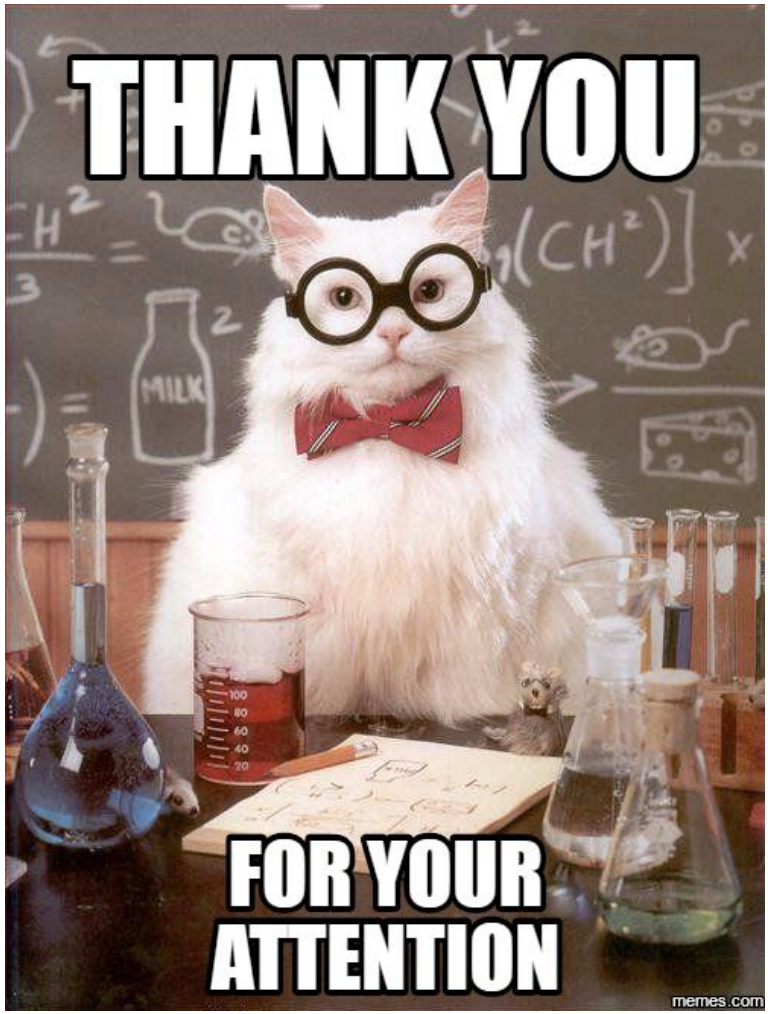
Segmented image

Classified image

Performance scores

Confusion matrices

Optimized parameters



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