Remote sensing and machine learning:
Towards a spatio-temporal continuous monitoring of the environment

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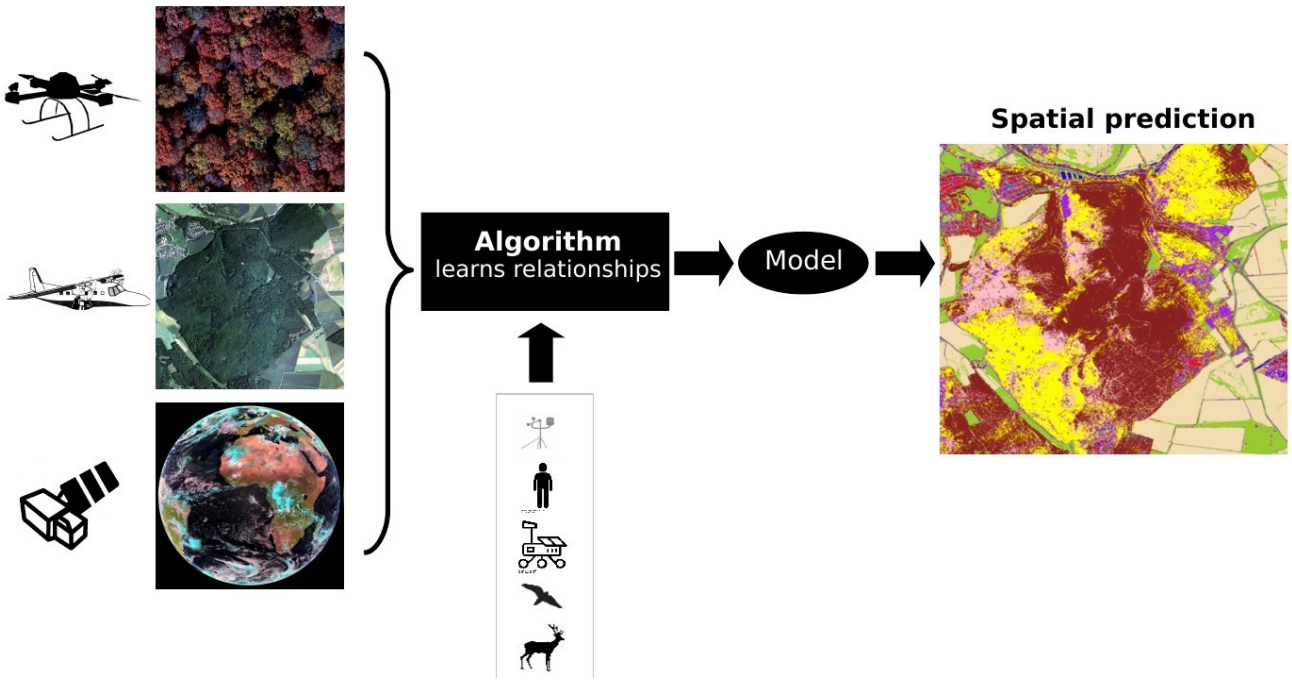


Part 1: Introduction to remote sensing data

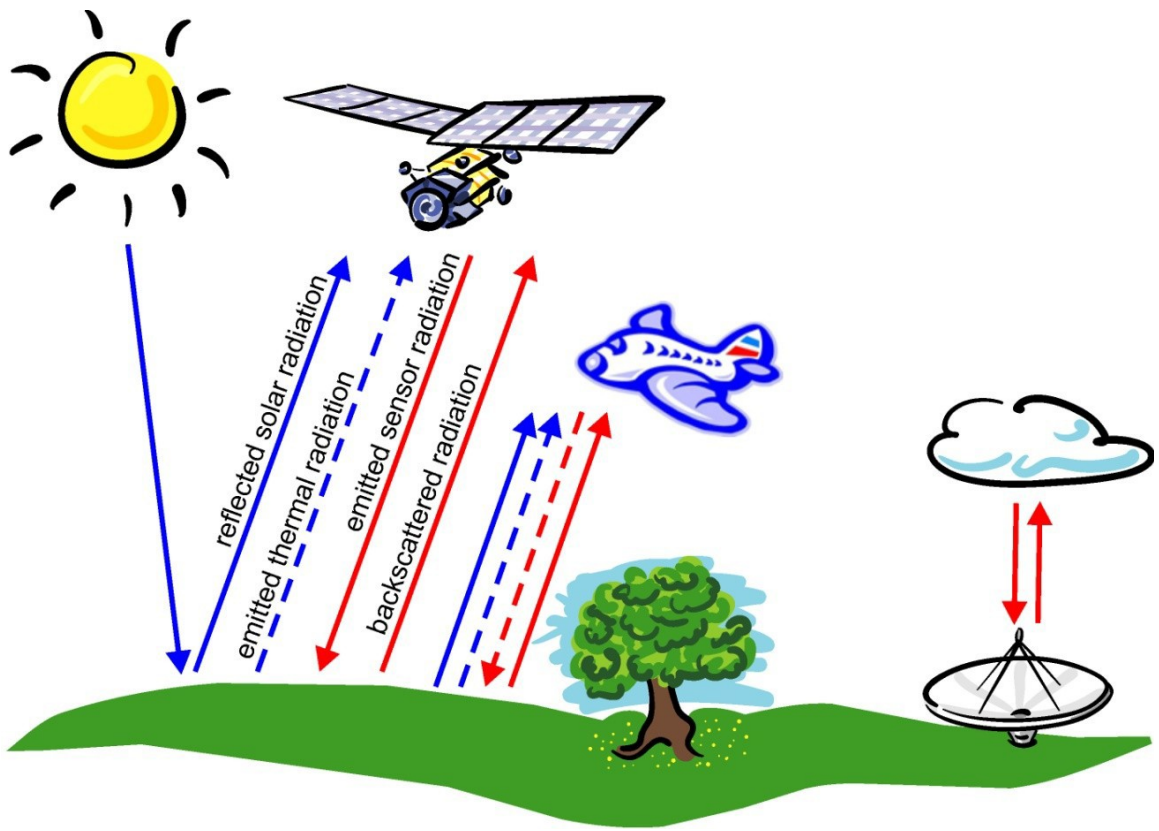
What are remote sensing data?

Passive Sensors

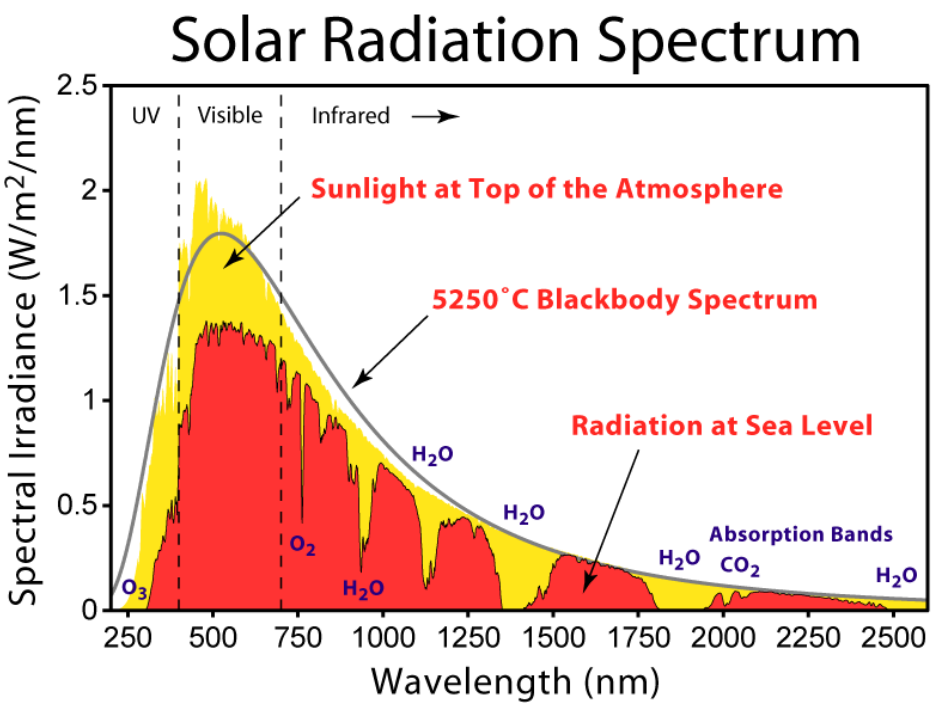
- Natural source of radiation
  - Solar radiation
  - Terrestrial radiation
- Broad spectrum
  - UV/VIS/NIR
  - TIR

Active Sensors

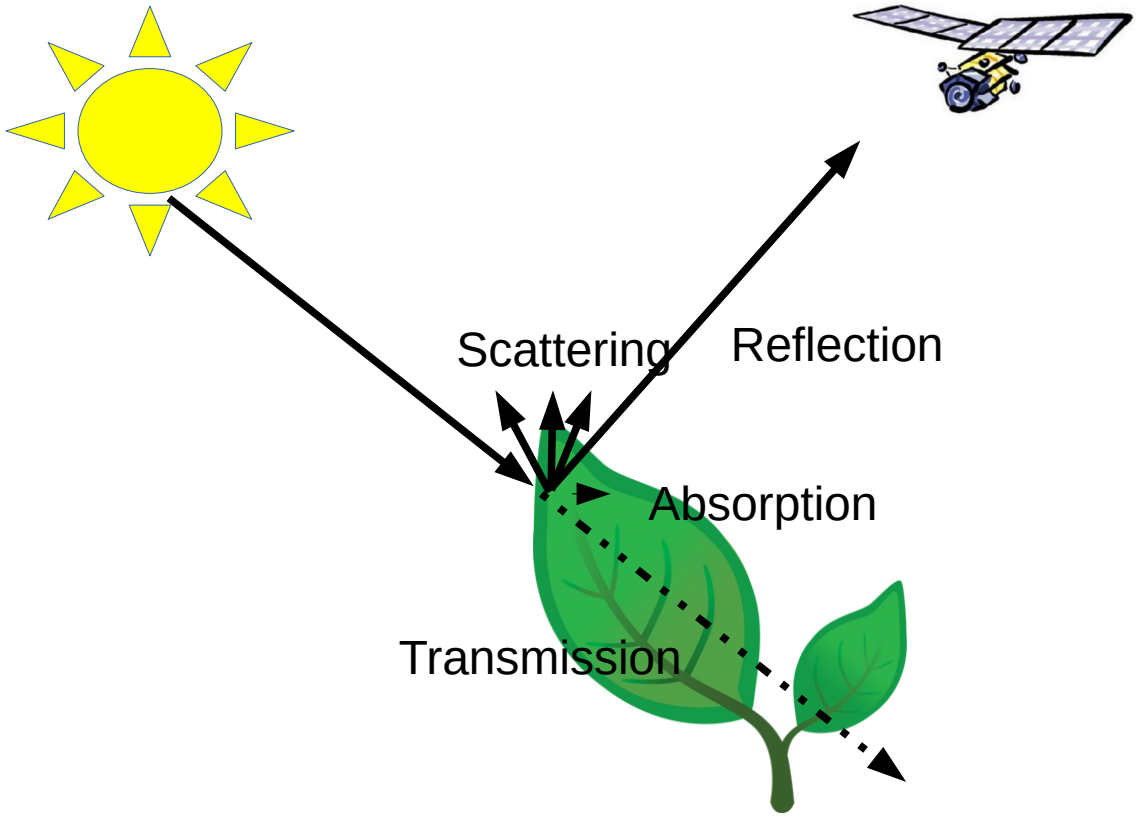
- Artifical source of radiation
  - LiDAR
  - Radar



Solar radiation and reflection properties



https://commons.wikimedia.org/wiki/File:Solar_Spectrum.png

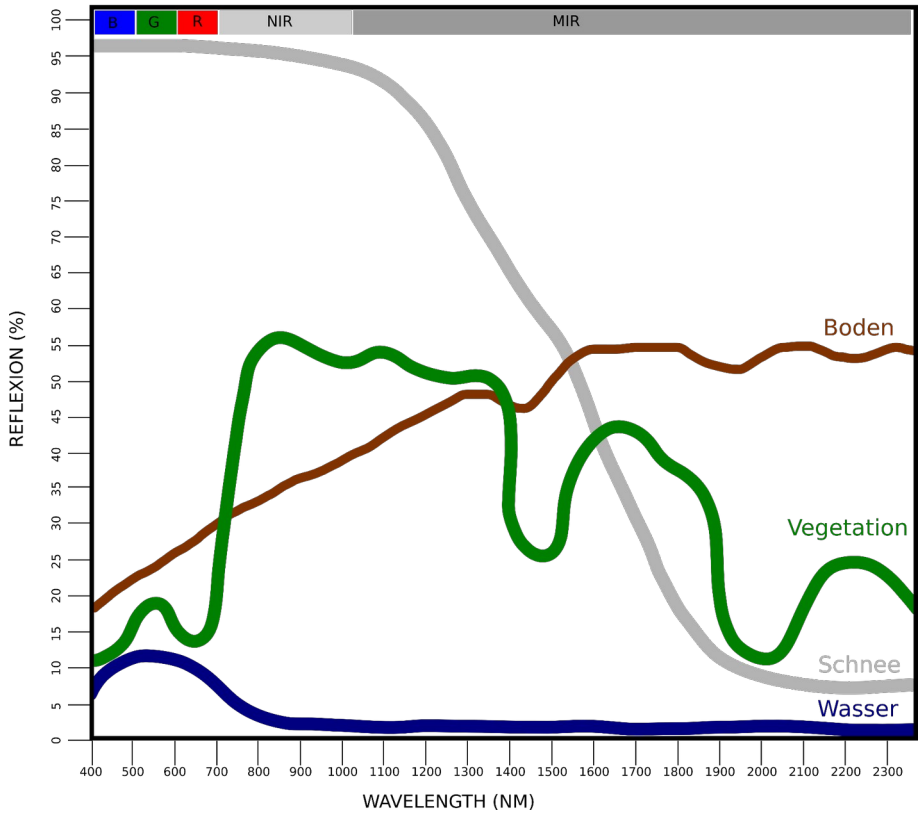


Solar radiation and reflection properties

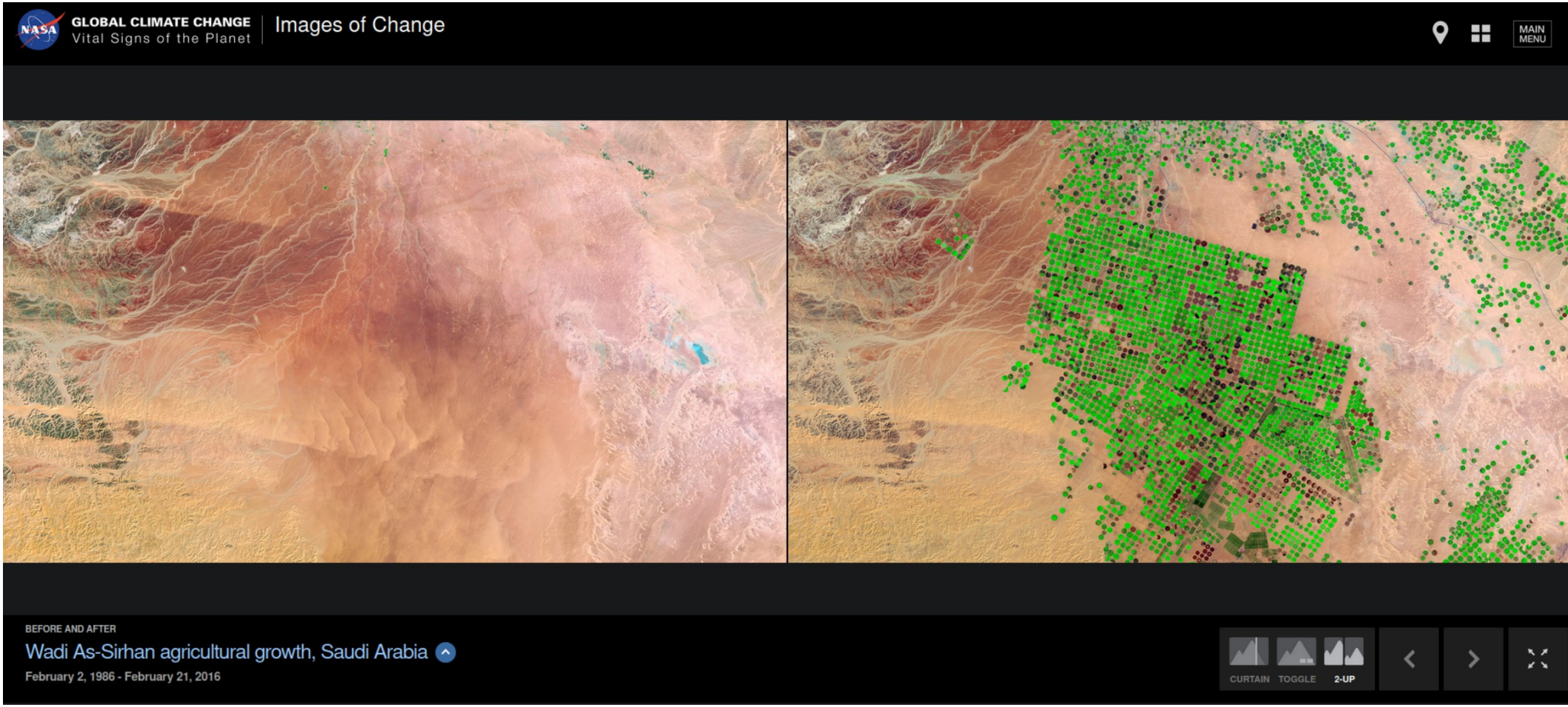
- Different objects reflect differently in different wavelengths

  → Characteristic reflection curves

- Basis for land cover classifications
- Also differences depending on e.g. vegetation health



Detecting land cover and land cover change



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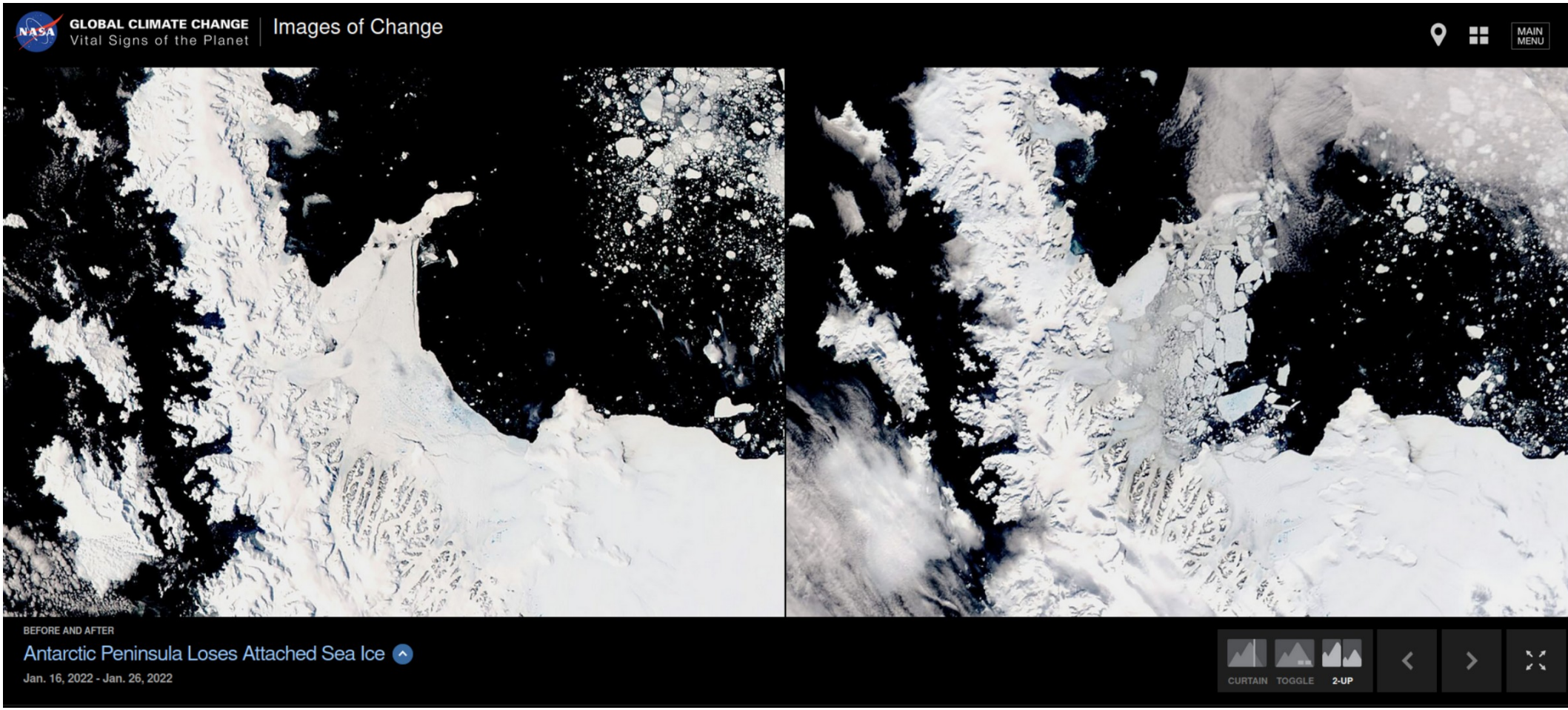

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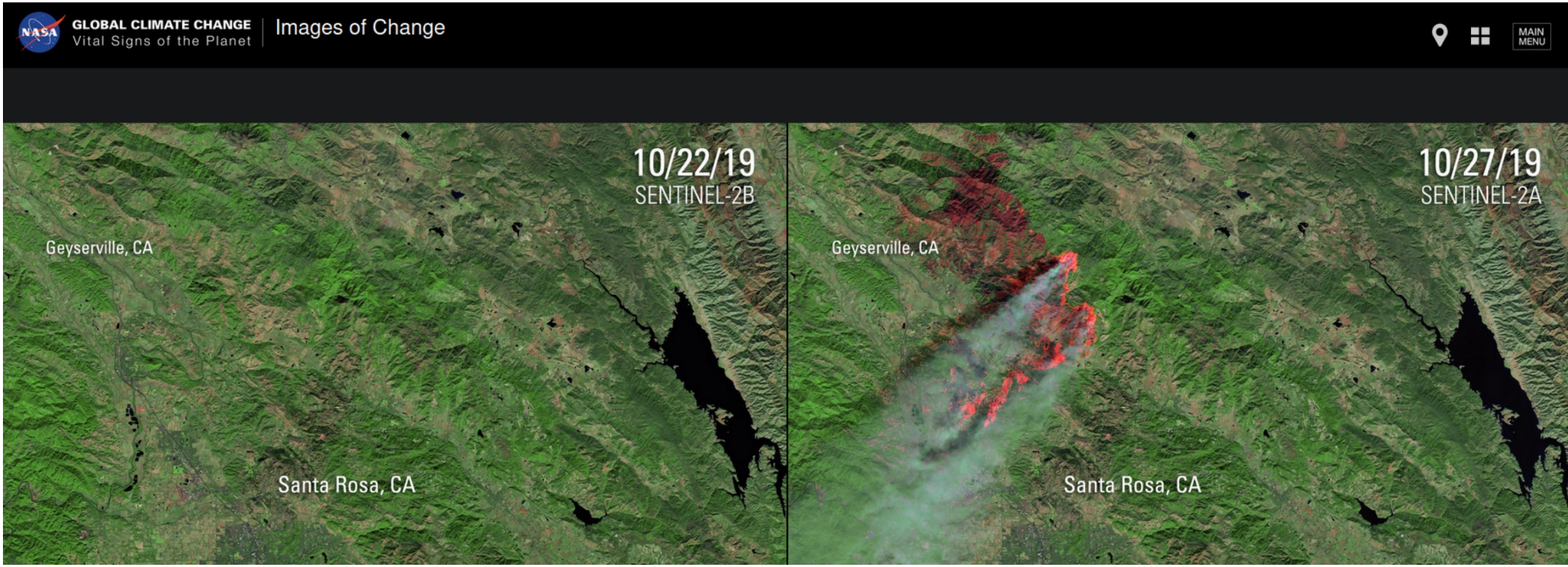
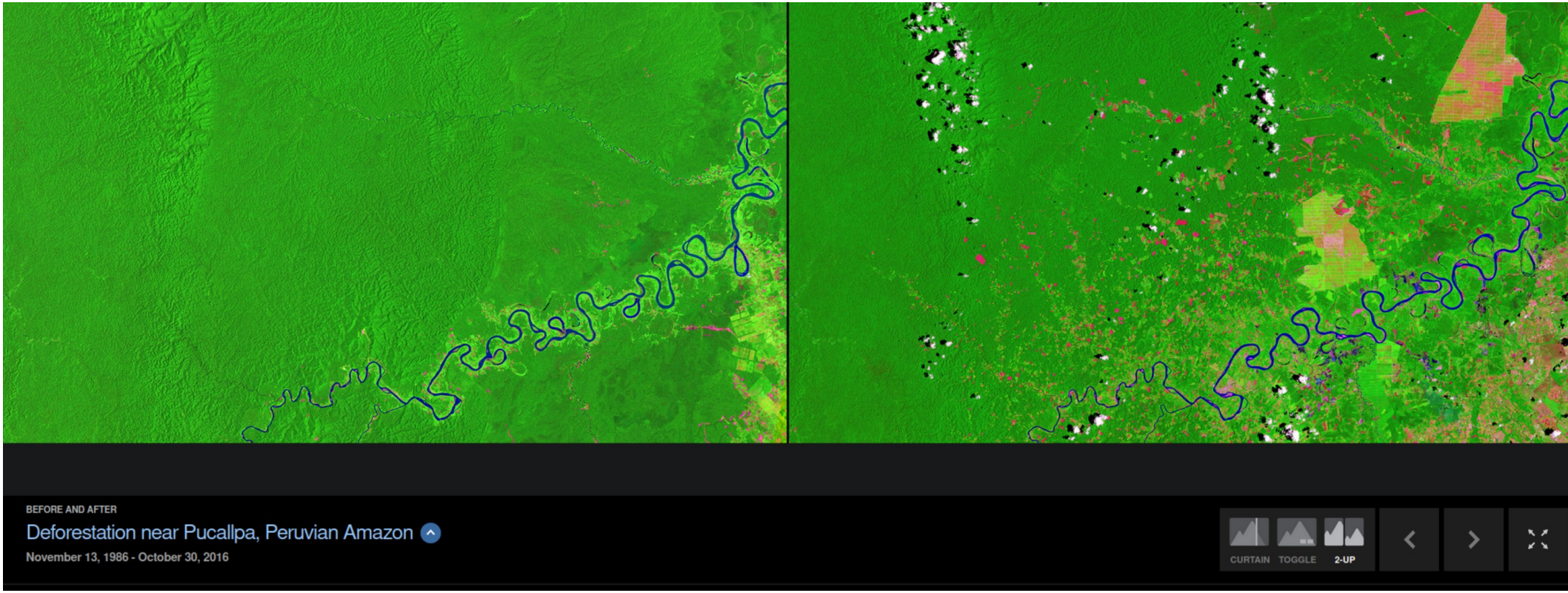


Detecting land cover and land cover change



So let’s get some satellite data… but from which satellite?

Platform/Sensor	Spatial resolution (m)	Temporal resolution	Availability
Landsat MSS	79	16 days	since 1972
Landsat TM	30	16 days	since 1982
Landsat ETM+	30	16 days	since 1999
Landsat 8 (OLI)	30	16 days	since 2013
Sentinel-2	10	5/10 days	since 2014
MODIS Terra/Aqua	250-1000	4 per day	since 2000
Meteosat Second Generation	3000	15 minutes	since 2002

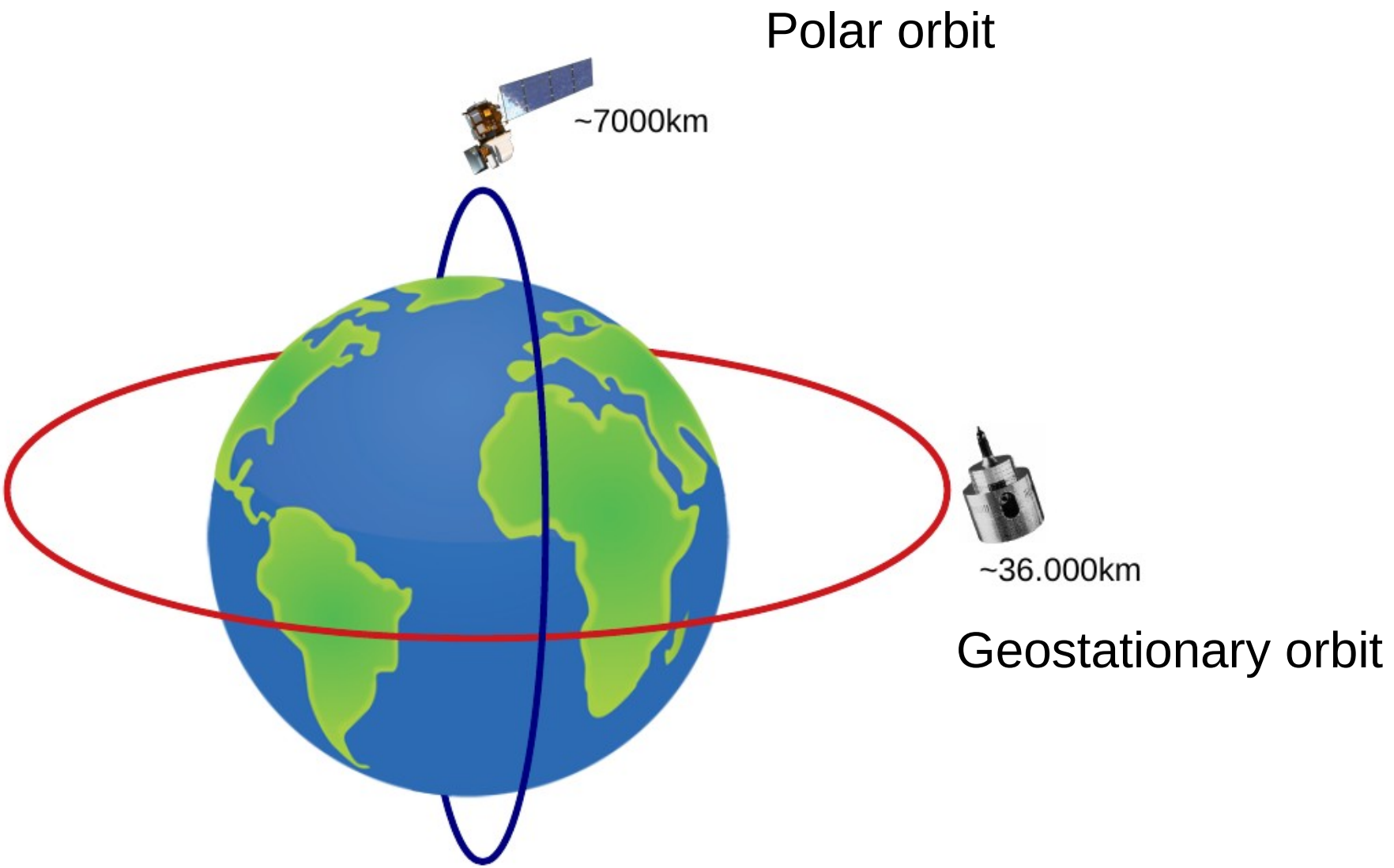
Which data to use? Spatial resolution

Aerial image (Google Earth): <1m

Landsat-scale: 30m

MODIS-scale: 500m

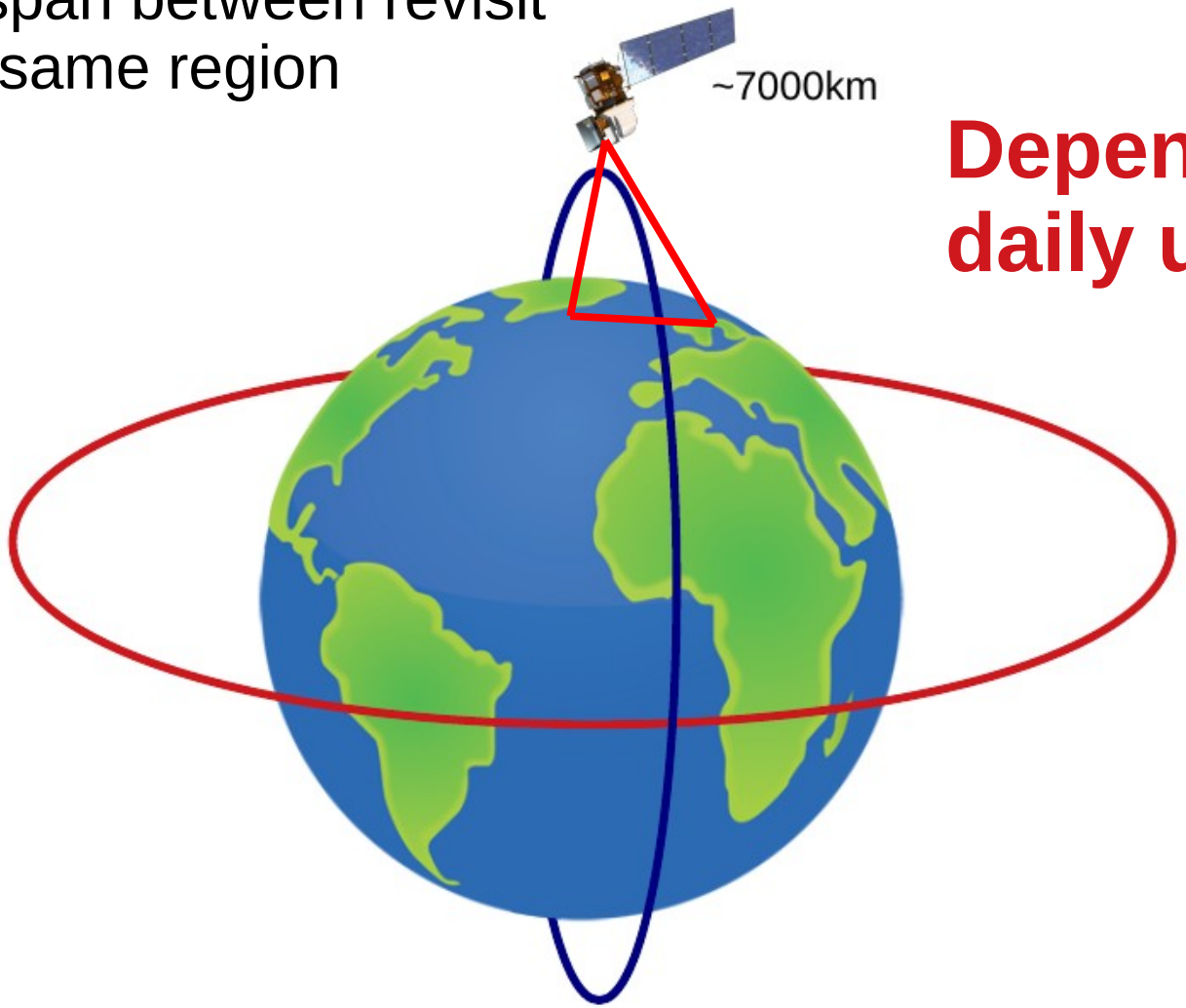
Which data to use? Temporal resolution



Which data to use? Temporal resolution

Time span between revisit of the same region

Polar orbit



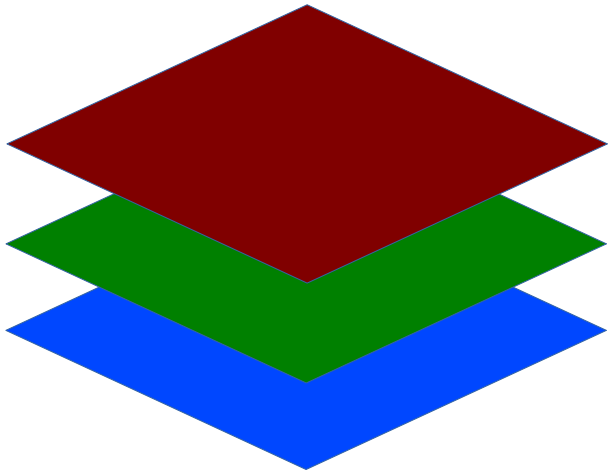
Depending on Swath. daily up to ~14 days

Geostationary orbit

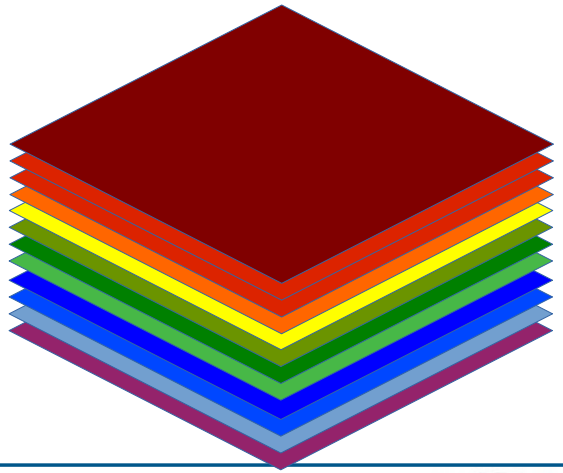
ca. 15 min

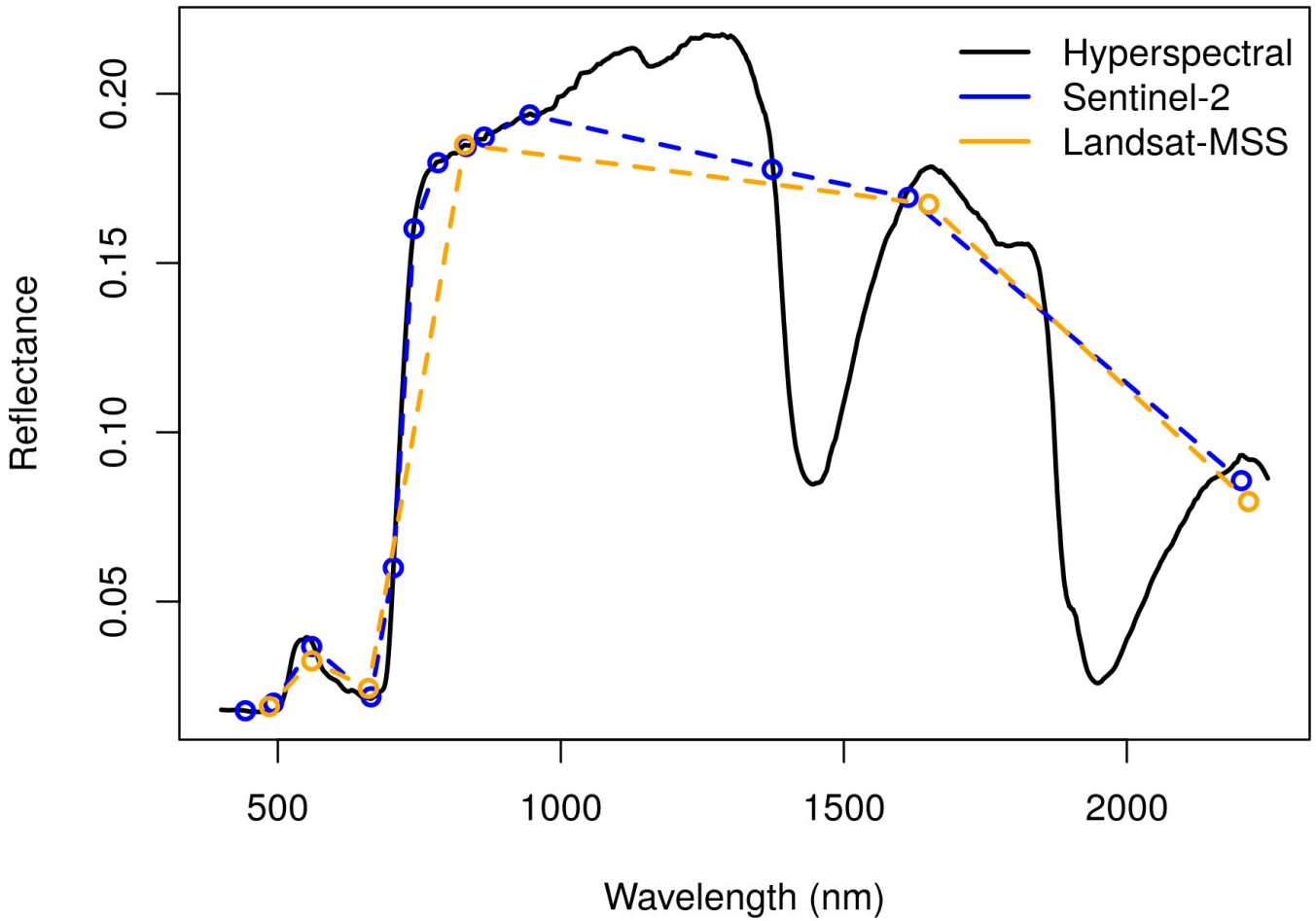
Which data to use? Spectral resolution

Multispectral



Hyperspectral





Spectral resolution of Sentinel-2 data

Platform/Sensor	Spatial resolution (m)	Temporal resolution	Availability
Landsat MSS	79	16 days	since 1972
Landsat TM	30	16 days	since 1982
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Spectral bands for the Sentinel-2 sensors[9]

Sentinel-2 bands	Sentinel-2A		Sentinel-2B		
	Central wavelength (nm)	Bandwidth (nm)	Central wavelength (nm)	Bandwidth (nm)	Spatial resolution (m)
Band 1 – Coastal aerosol	442.7	21	442.2	21	60
Band 2 – Blue	492.4	66	492.1	66	10
Band 3 – Green	559.8	36	559.0	36	10
Band 4 – Red	664.6	31	664.9	31	10
Band 5 – Vegetation red edge	704.1	15	703.8	16	20
Band 6 – Vegetation red edge	740.5	15	739.1	15	20
Band 7 – Vegetation red edge	782.8	20	779.7	20	20
Band 8 – NIR	832.8	106	832.9	106	10
Band 8A – Narrow NIR	864.7	21	864.0	22	20
Band 9 – Water vapour	945.1	20	943.2	21	60
Band 10 – SWIR – Cirrus	1373.5	31	1376.9	30	60
Band 11 – SWIR	1613.7	91	1610.4	94	20
Band 12 – SWIR	2202.4	175	2185.7	185	20

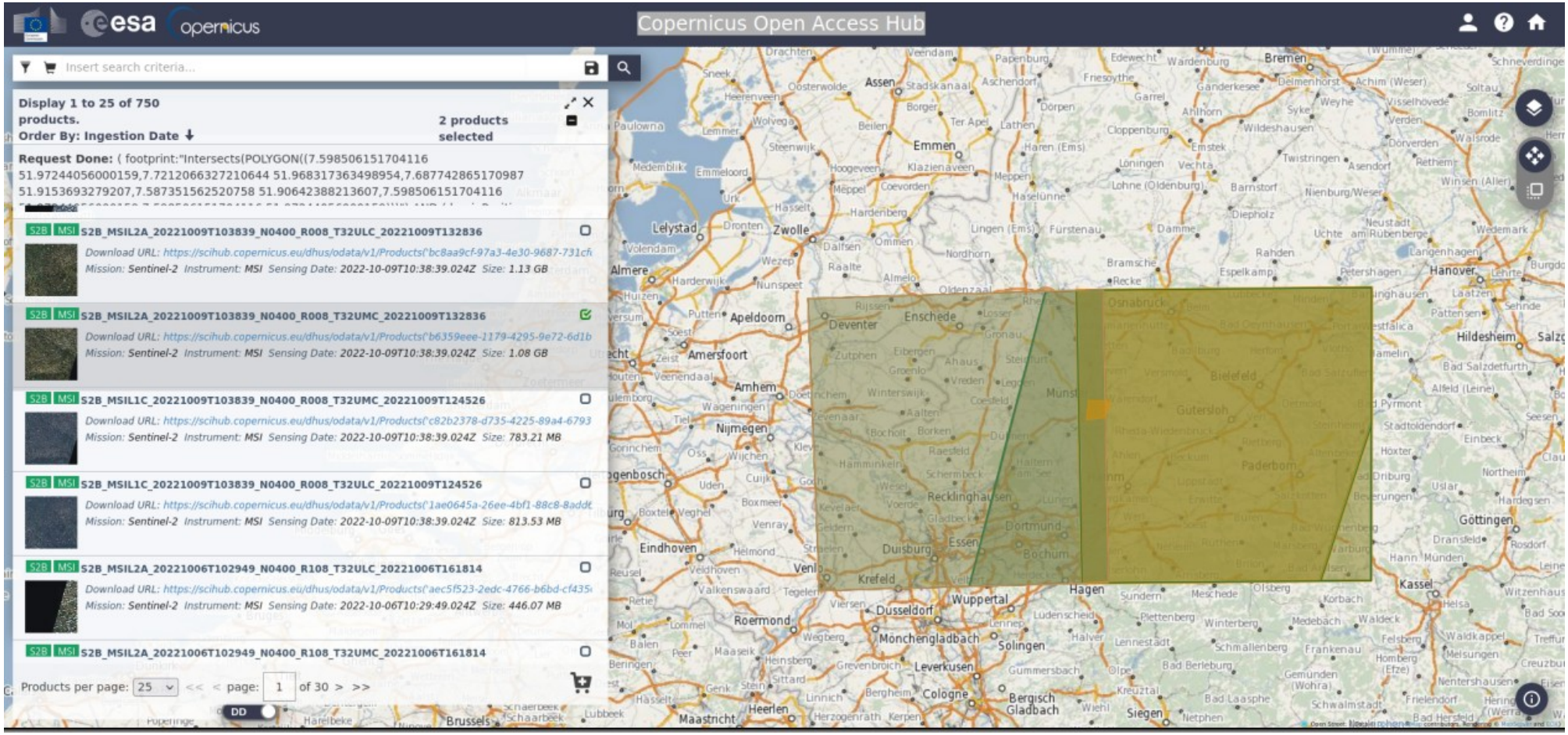
https://en.wikipedia.org/wiki/Sentinel-2

Which data for which purpose?

- What spectral resolution is required to detect the target objects?
- What spatial resolution is required (how large are the objects). High resolution is not always advantageous (amount of data, noise)
- Which time period and which temporal resolution is required (especially for change analyses)?

Getting satellite data

e.g. via Copernicus Open Access Hub: https://scihub.copernicus.eu

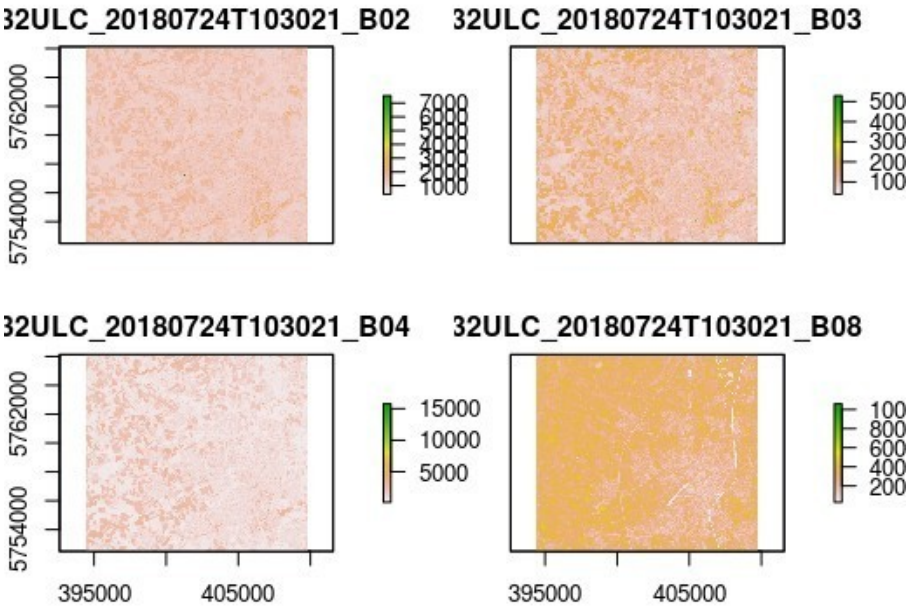


Load satellite data in R

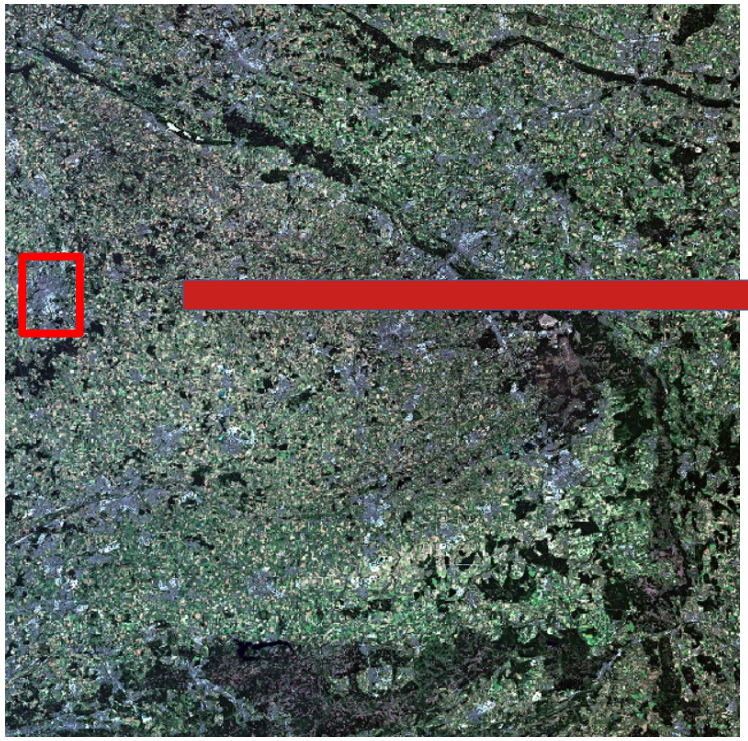
- Load the channels red,green,blue,NIR into R
- Load the 20m resolution channels as well and resample to 10m

How to import satellite data into R

```
library(terra)
sen <- rast(c("blue.tif","green.tif",
              "red.tif","NIR.tif"))
plot(sen)
```



Crop the data



100 km

Crop the multi-band raster to the area of interest (?crop)

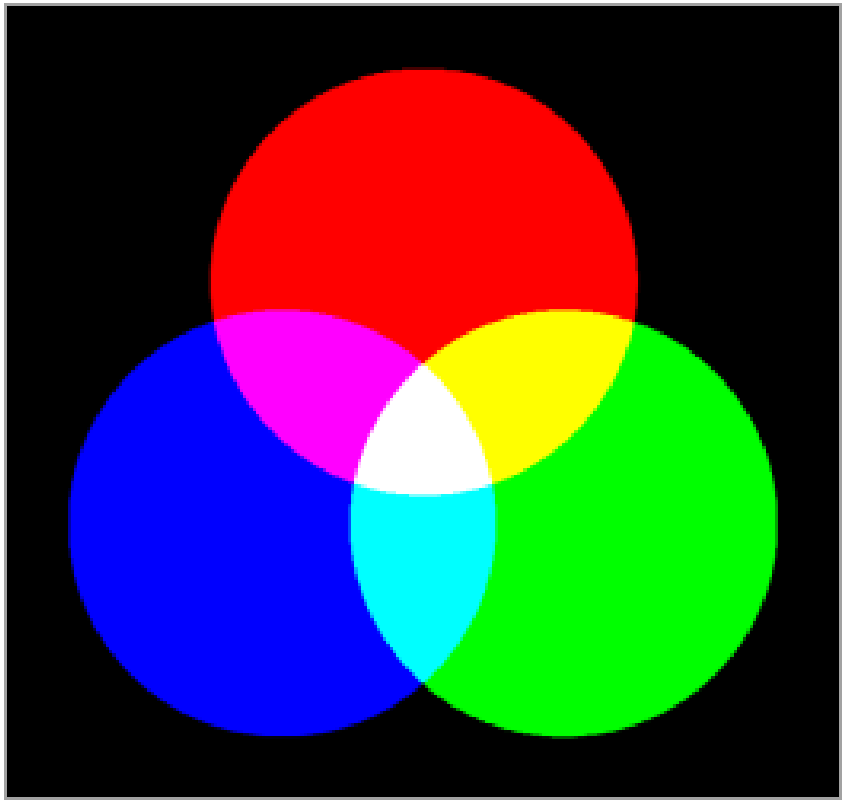
Crop the data

crop(sen, c(xmin, xmax, ymin, ymax))

Example Münster:
crop(sen, c(396260, 409060, 5749550, 5763830))

How do we get the “color” in the satellite data?

- Our eyes have three “sensors”: Blue, Green, Red
- Different colors through color mixing
- Idea: Combine visible channels to create a “true color composite”



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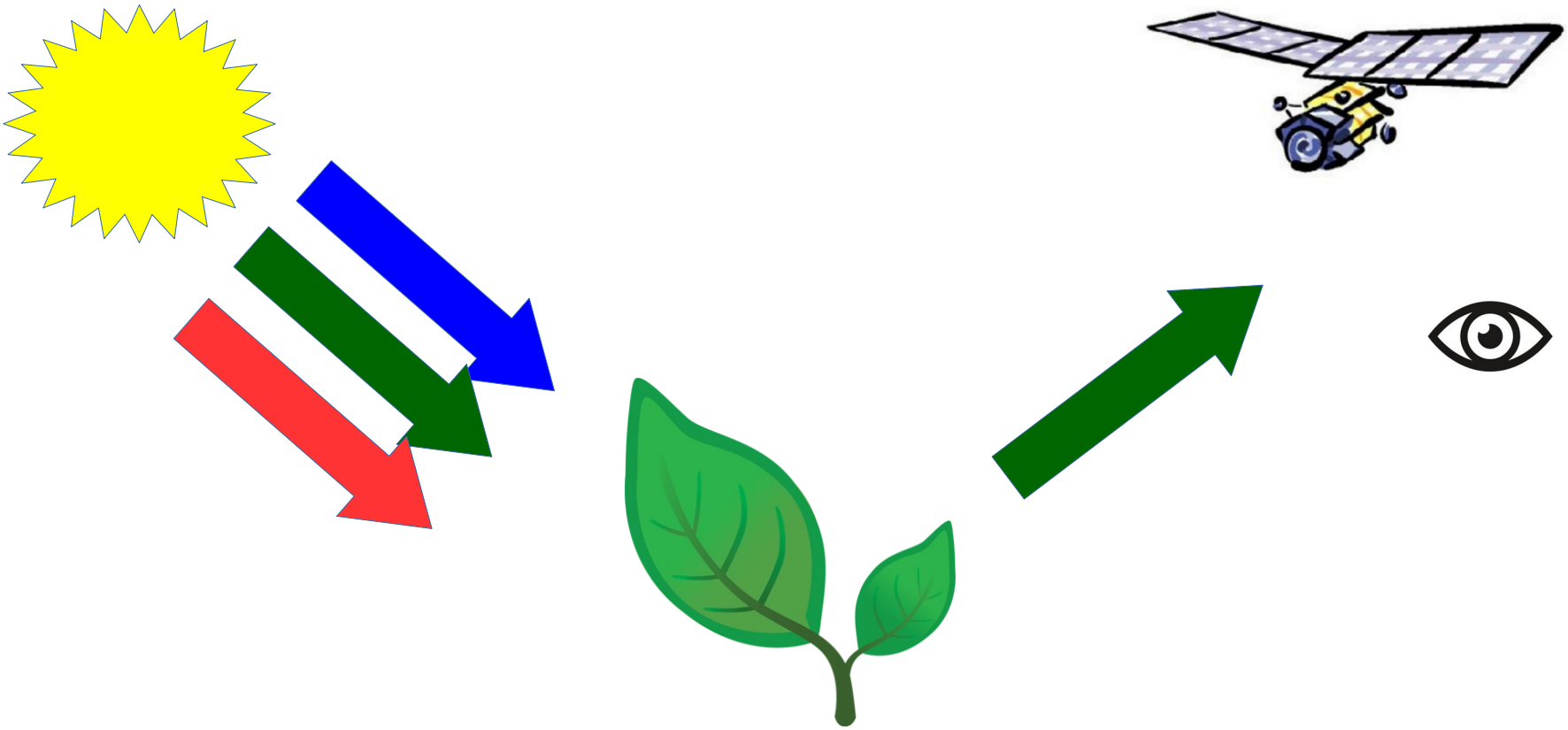

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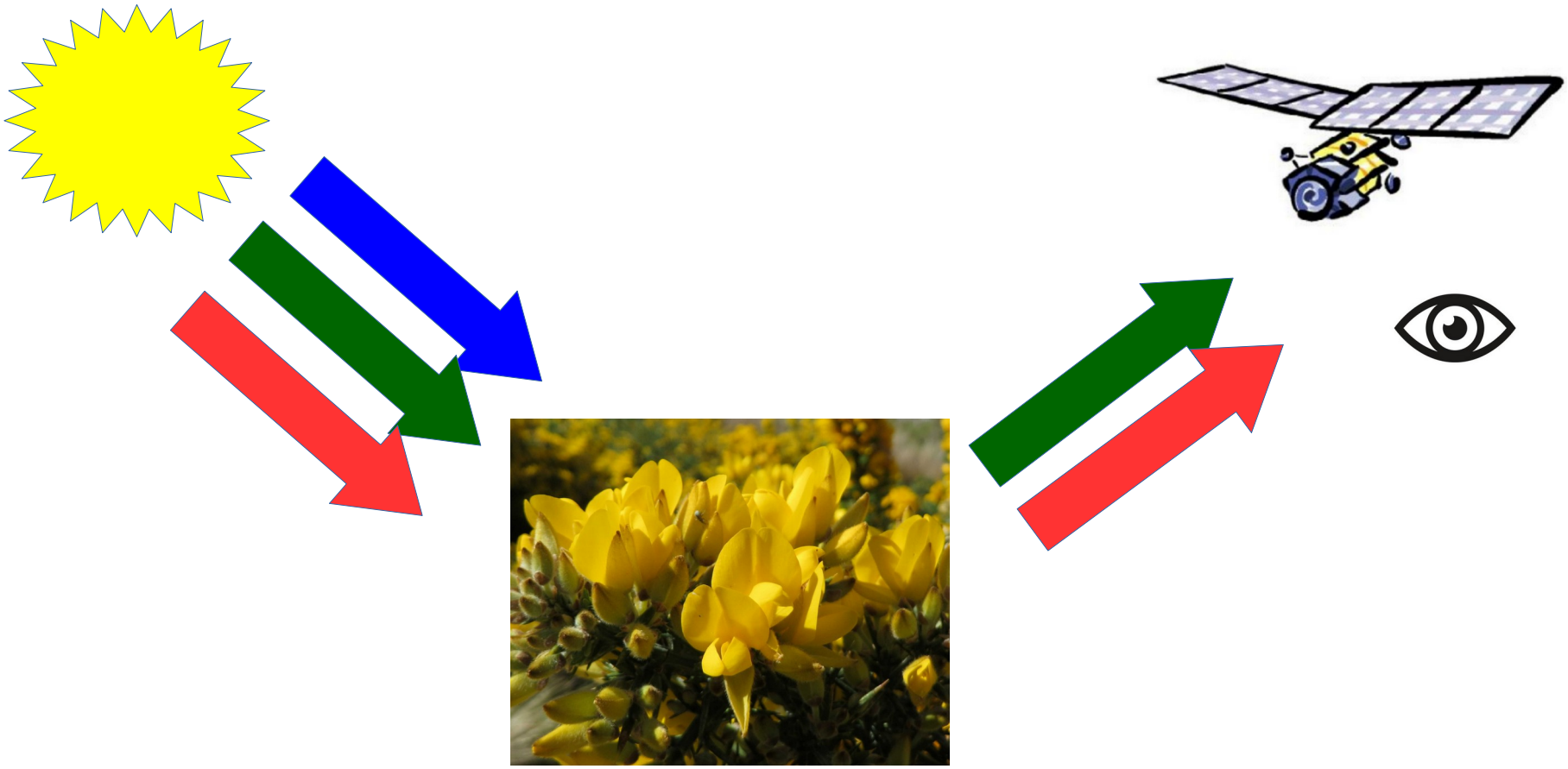

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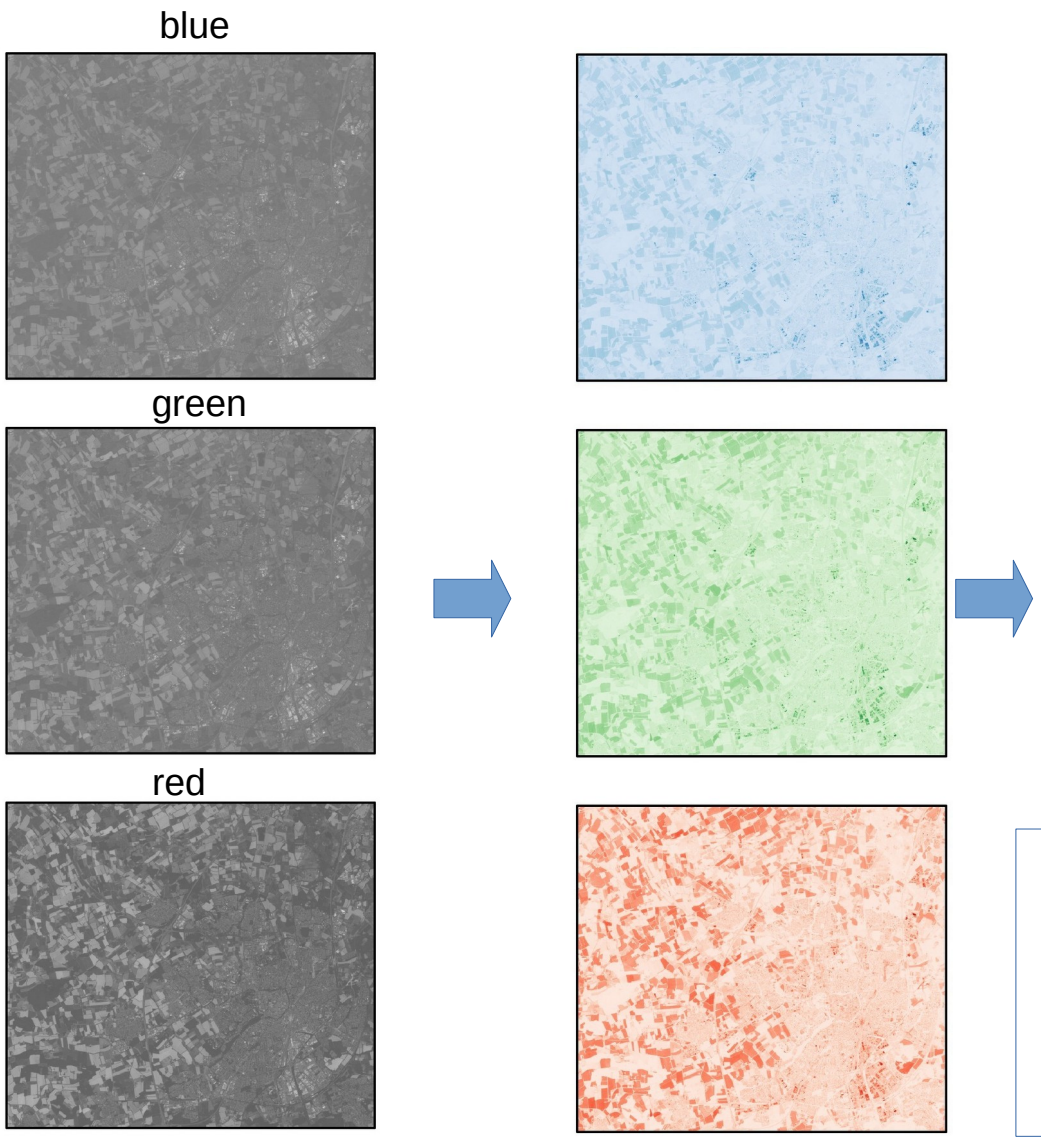


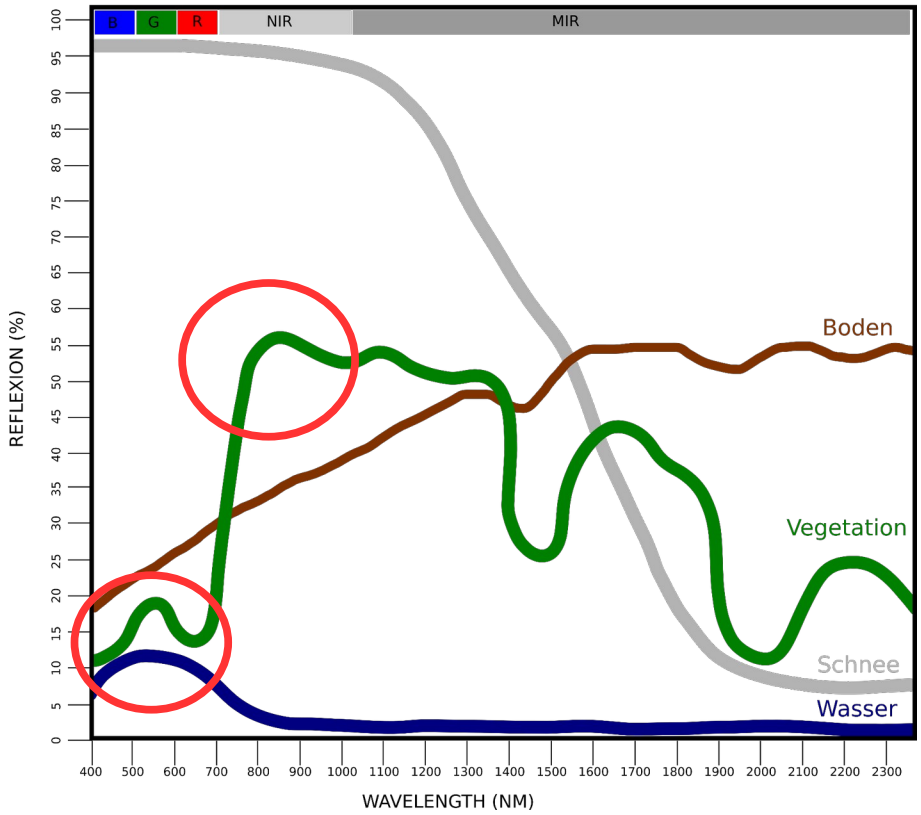
How to do a color composite in R

```
library(terra)
sen <- rast(c(“blue.tif”,”green.tif”,
        ”red.tif”,”NIR.tif”))
plotRGB(sen,r=3,g=2,b=1,stretch=”lin”)
```

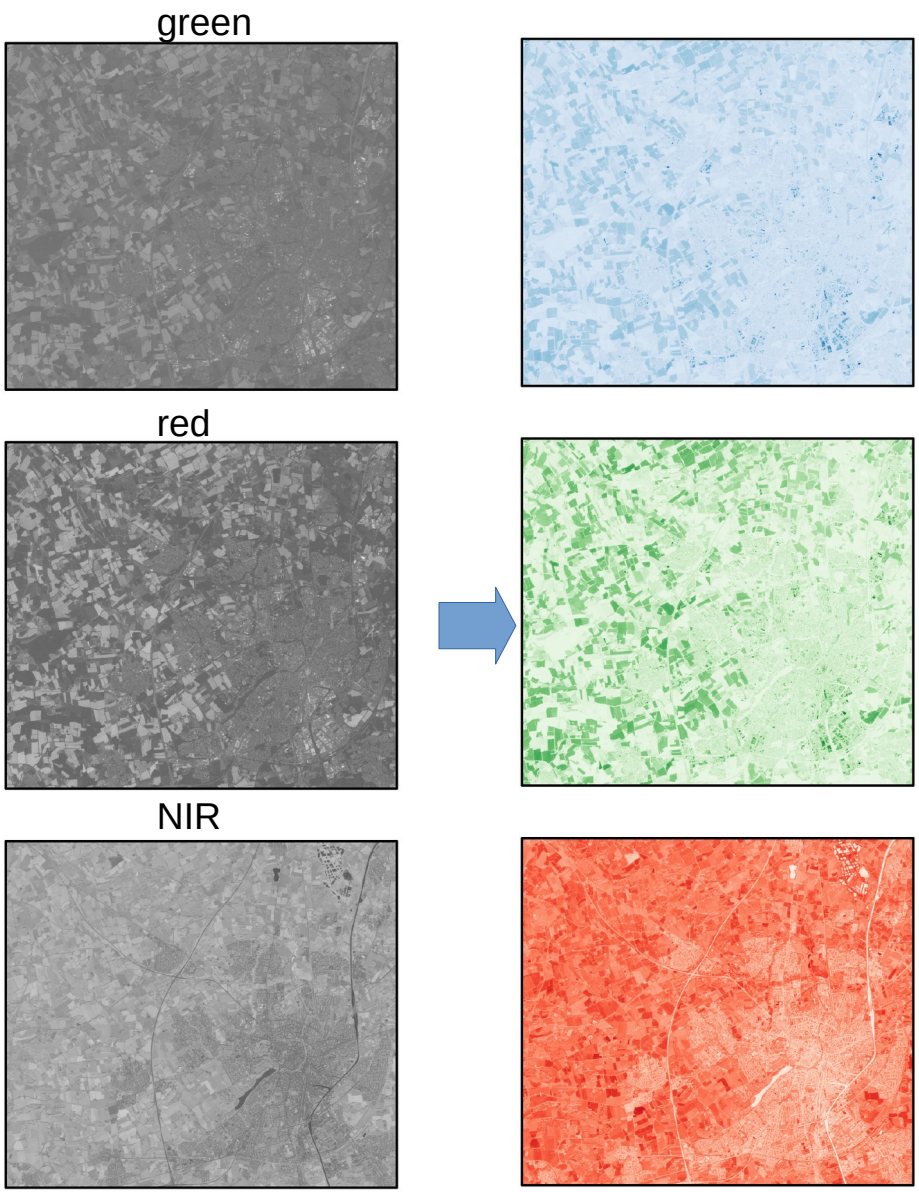
Artificial lawn or real grass?

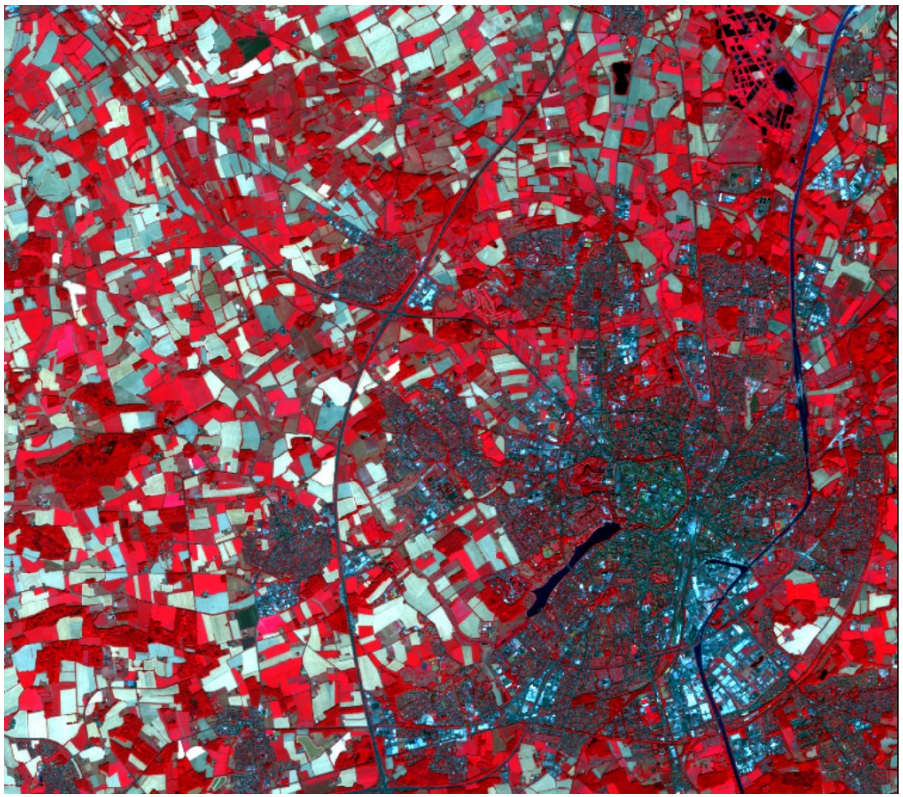
Marburg Uni-Stadion

Marburg Gaßmann-Stadion



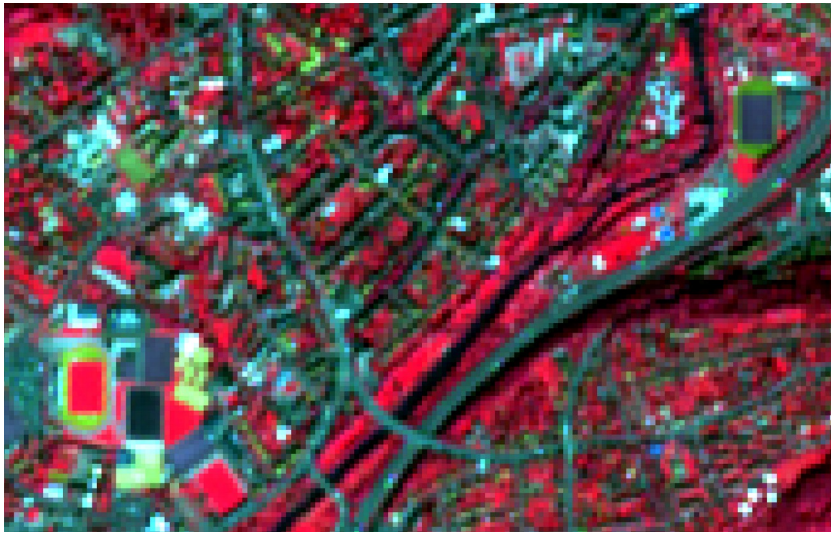
False color composite





Artificial lawn or real grass?

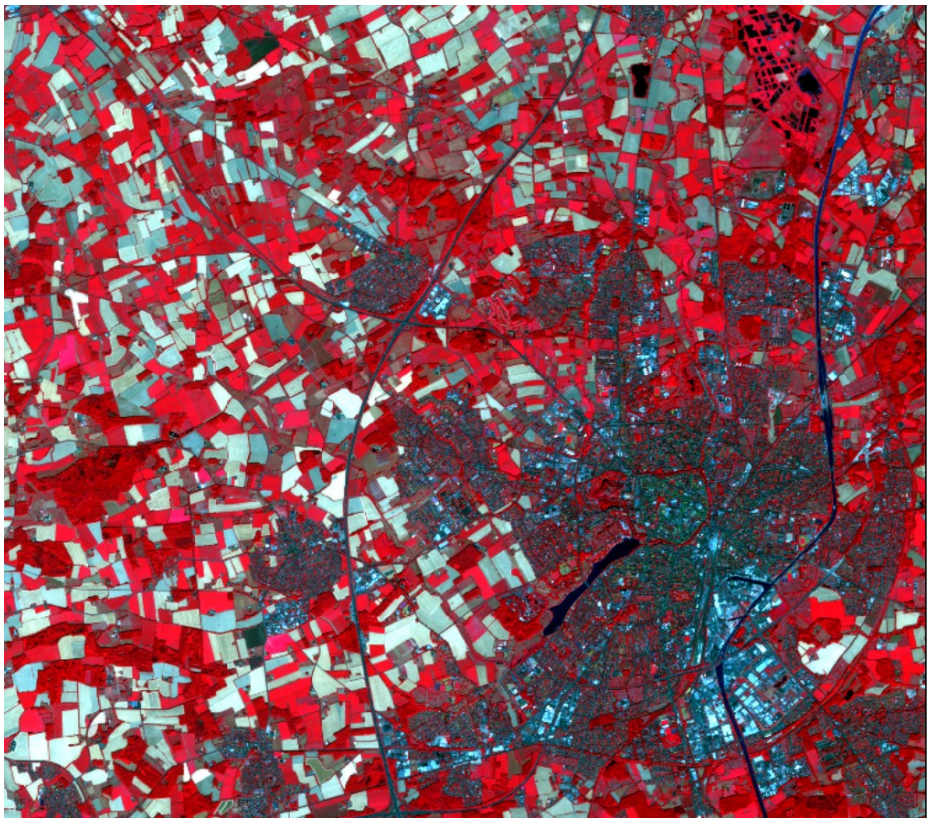
Marburg Uni-Stadion



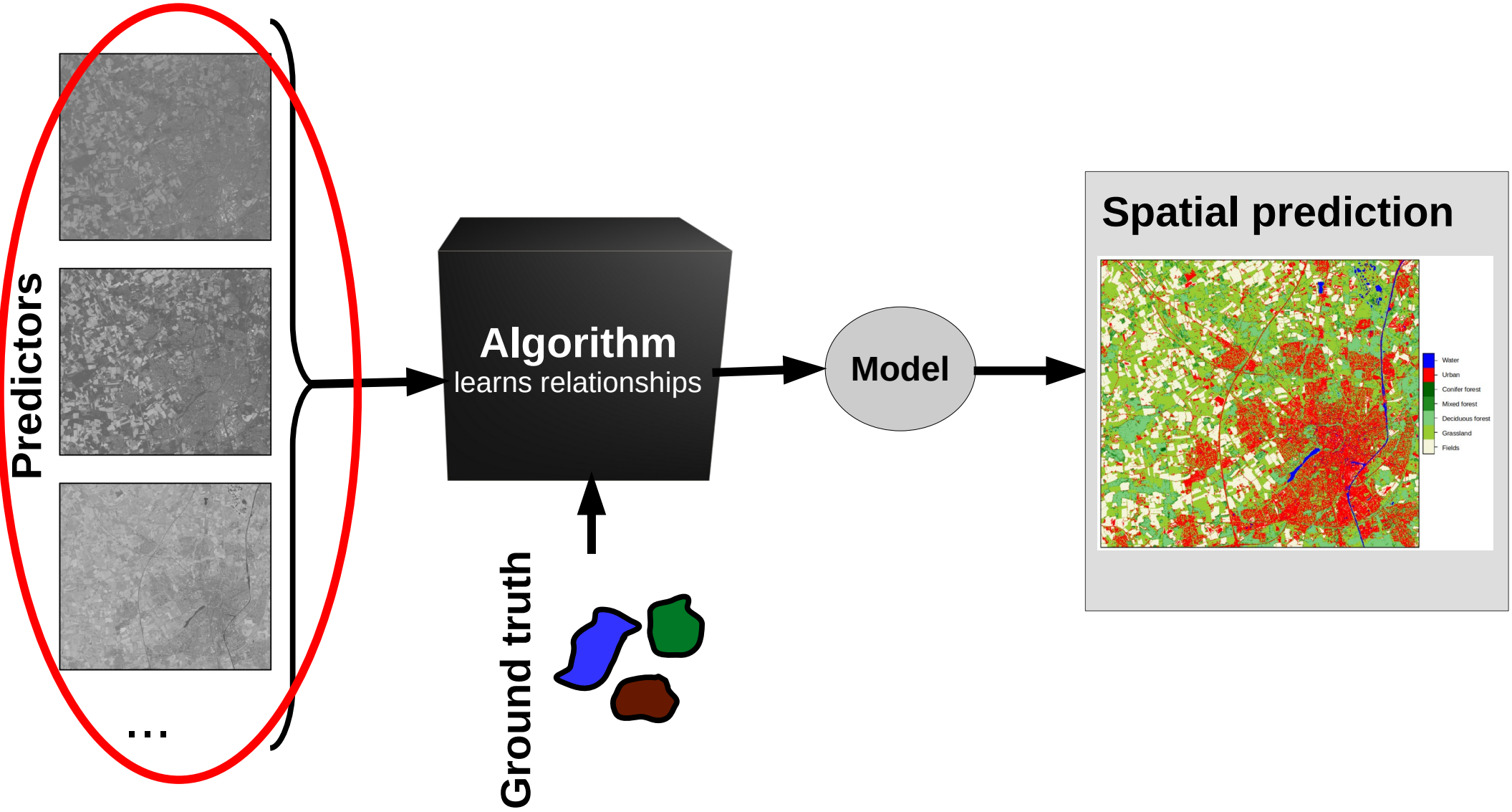
Marburg Gaßmann-Stadion

Task

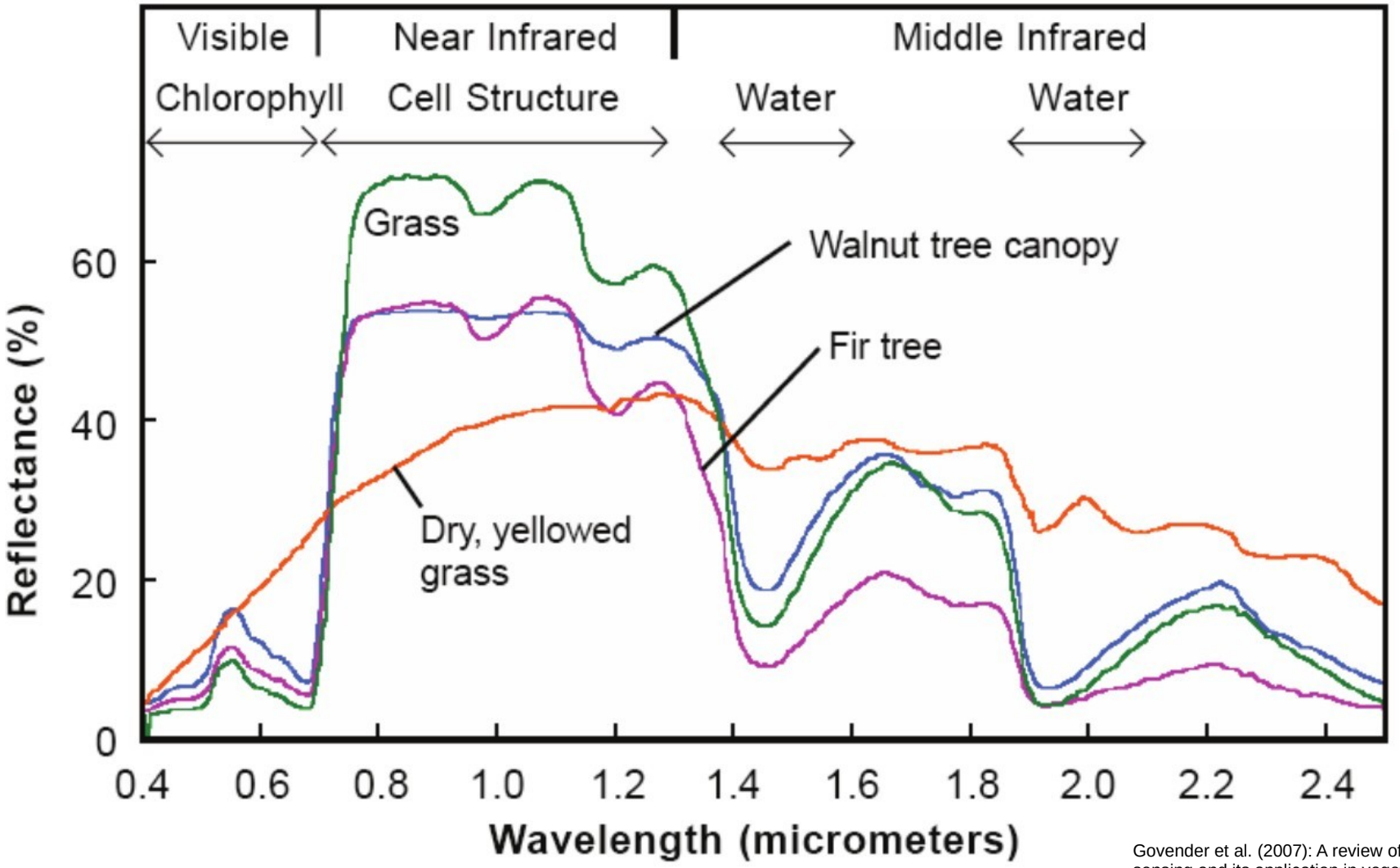
Visualize your image with a true color and a false color composite



Satellite-based predictors for land cover

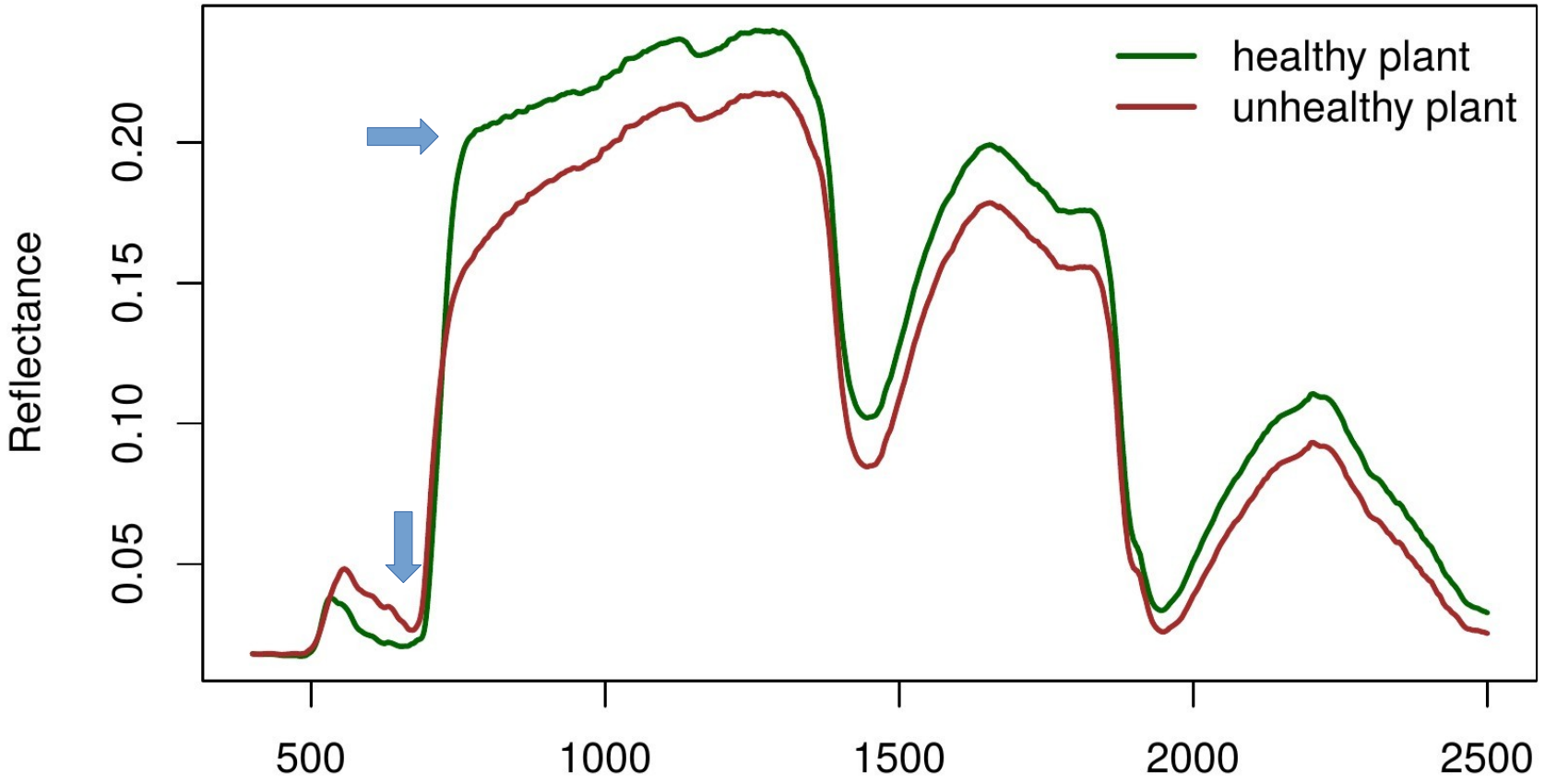


Further predictors: vegetation indices



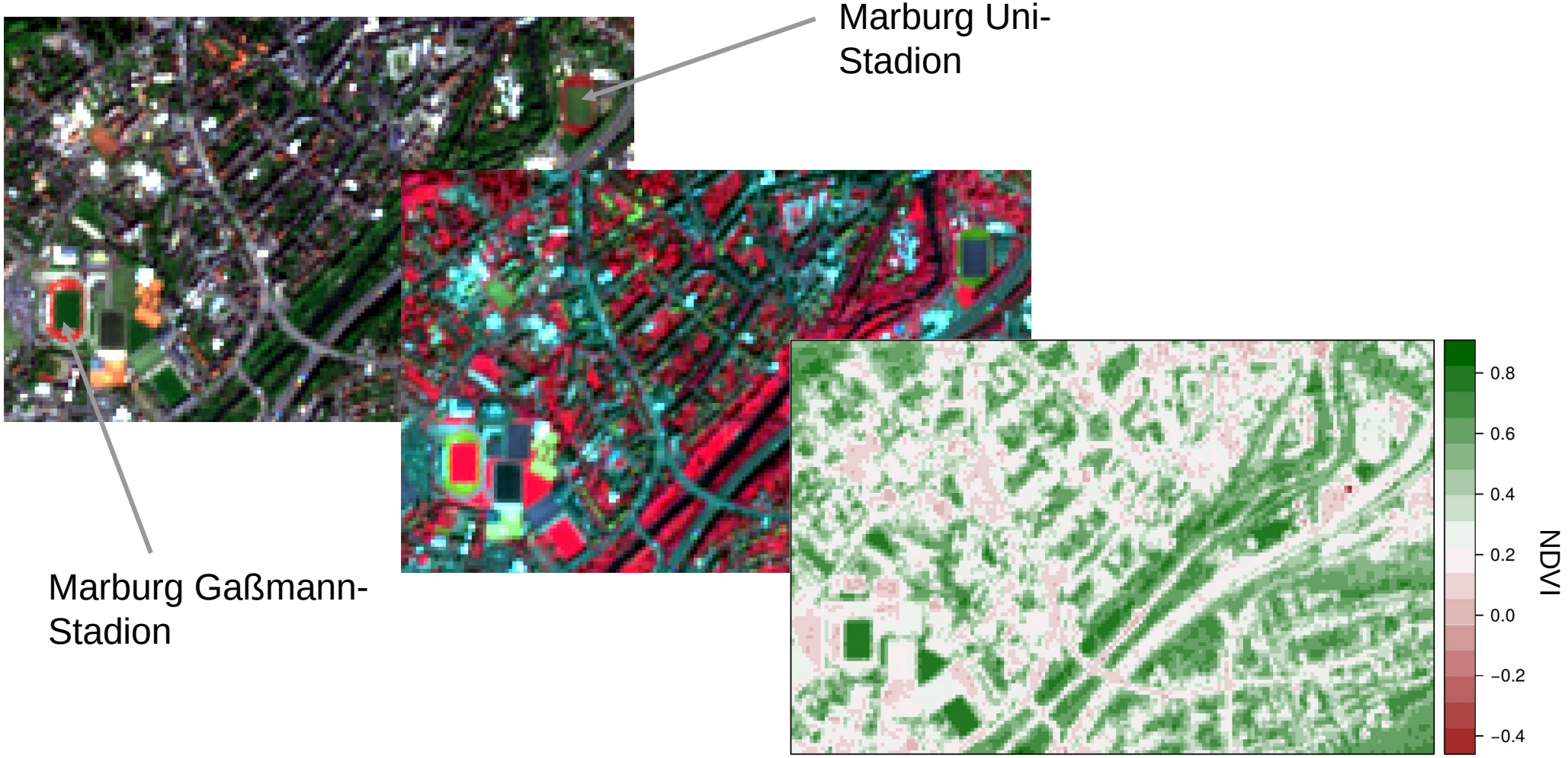
Govender et al. (2007): A review of hyperspectral remote sensing and its application in vegetation and water resource studies. Water S.A 33(2)

Further predictors: vegetation indices



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

Further predictors: vegetation indices



Further predictors: vegetation indices

Calculate the NDVI of the satellite scene

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

Compile predictors

Now make sure that you have the cropped raw channels as well as the NDVI in one raster group.
Write it to disk with ?writeRaster