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

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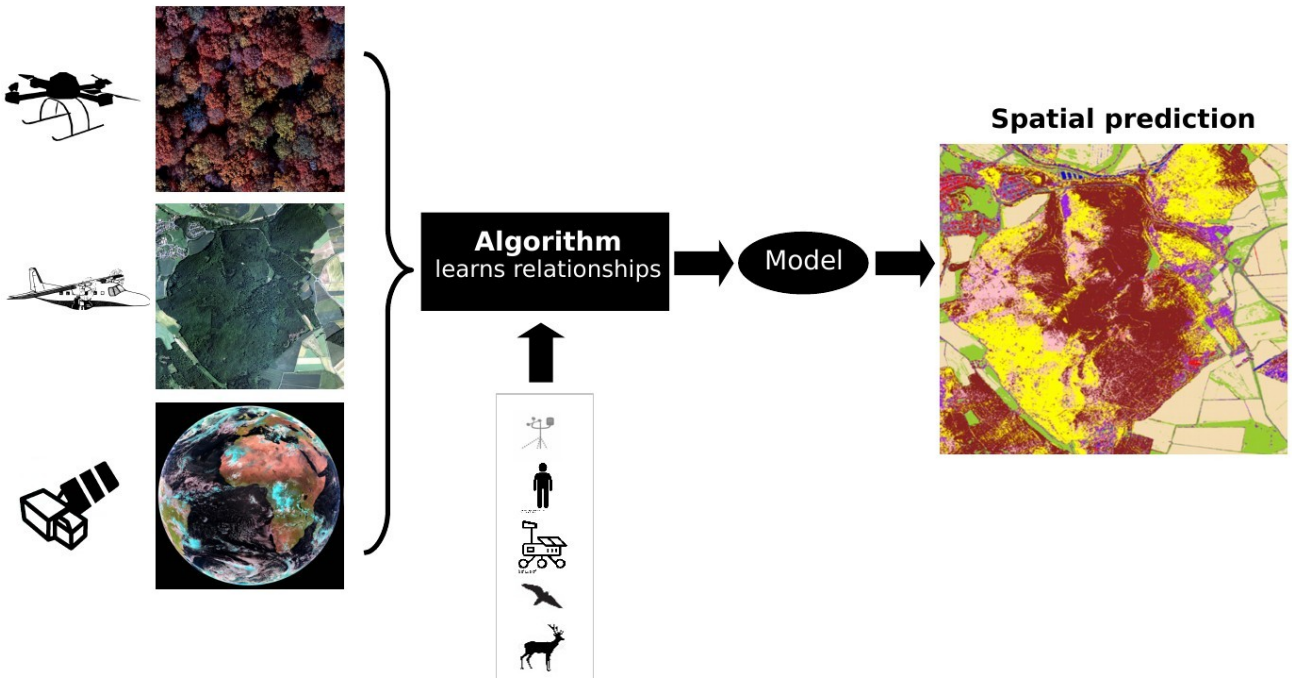


Part 1: Introduction to remote sensing data

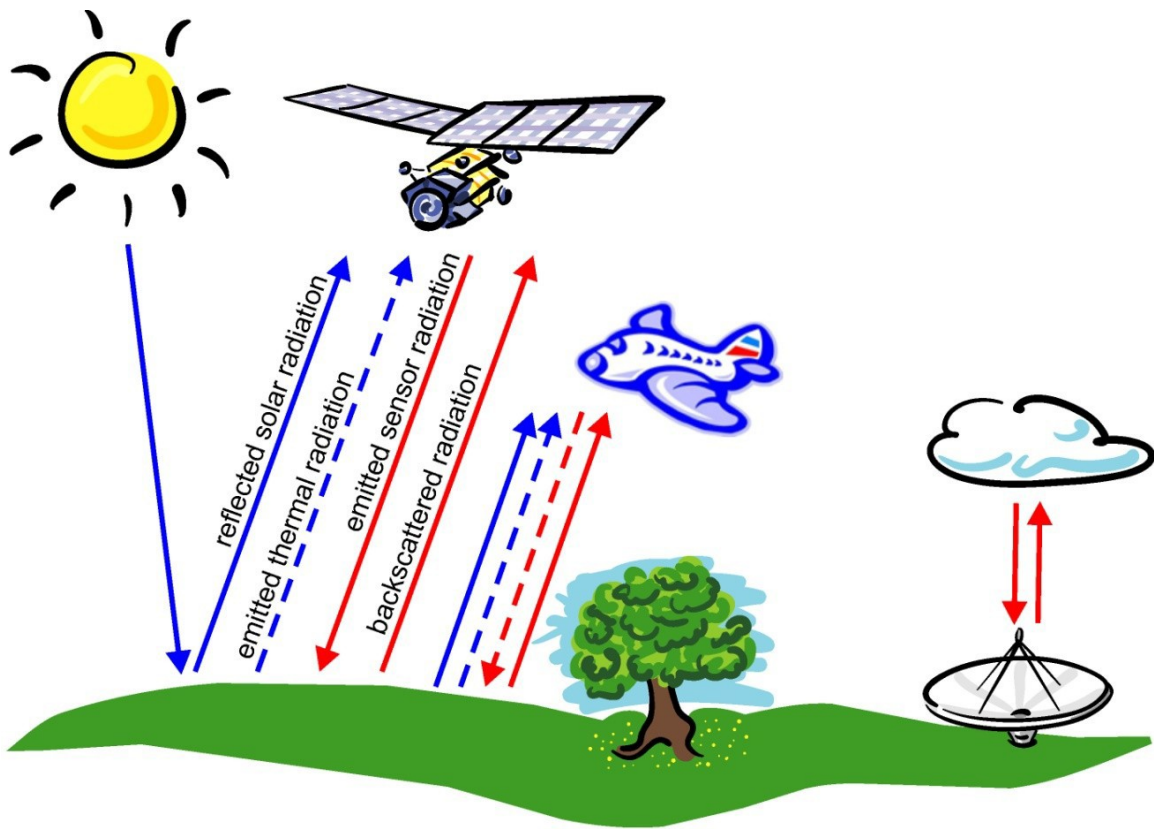
What are remote sensing data?

Passive Sensors

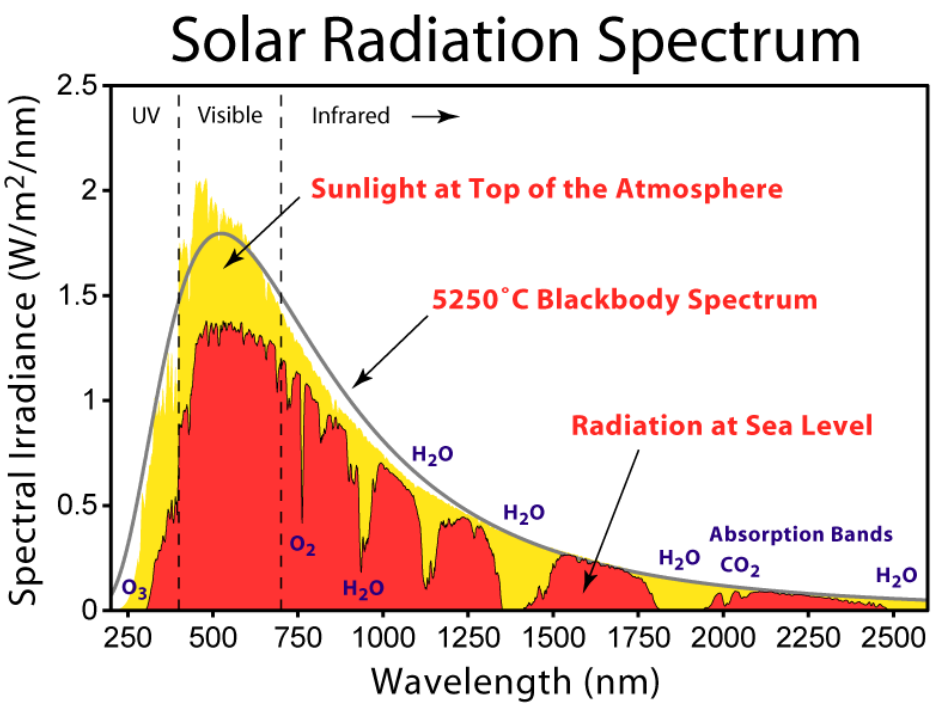
- Natural source of radiation
  - Solar radiation
  - Terrestrial radiation
- Broad spectrum
  - UV/VIS/NIR
  - TIR

Active Sensors

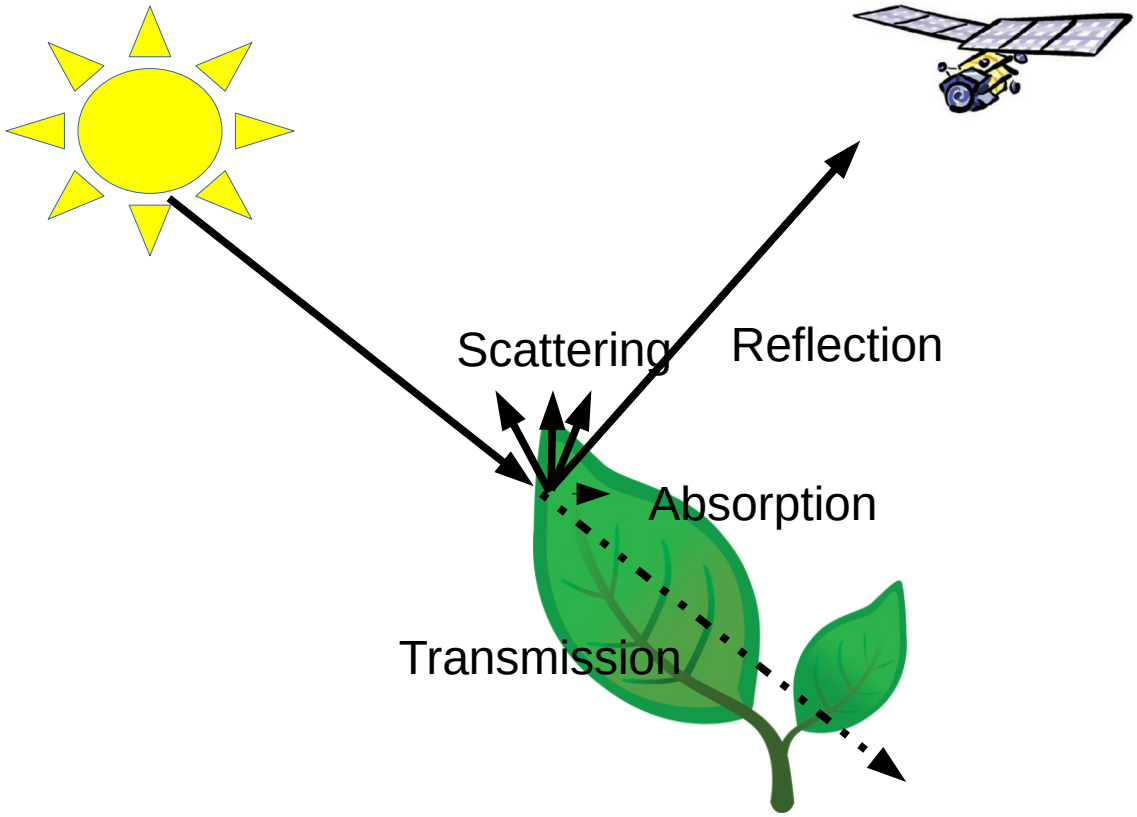
- Artifical source of radiation
  - LiDAR
  - Radar



Solar radiation and reflection properties



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

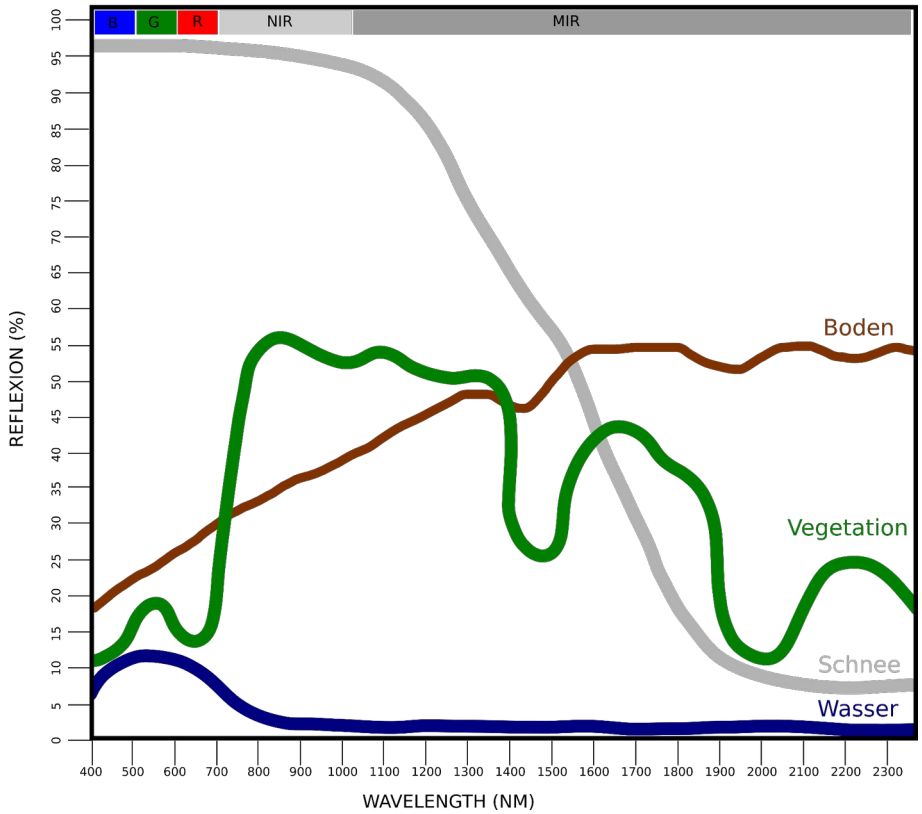


Solar radiation and reflection properties

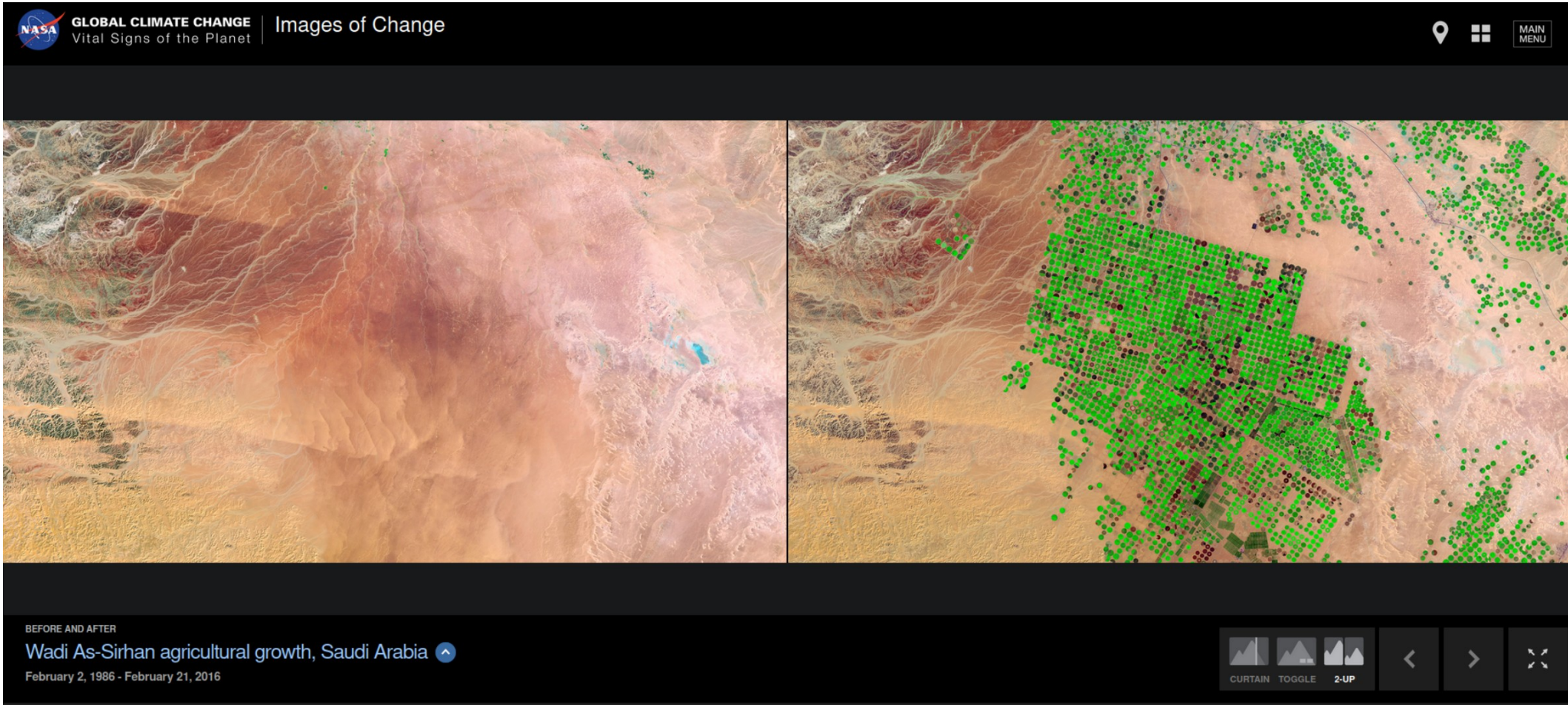
- Different objects reflect differently in different wavelengths

  → 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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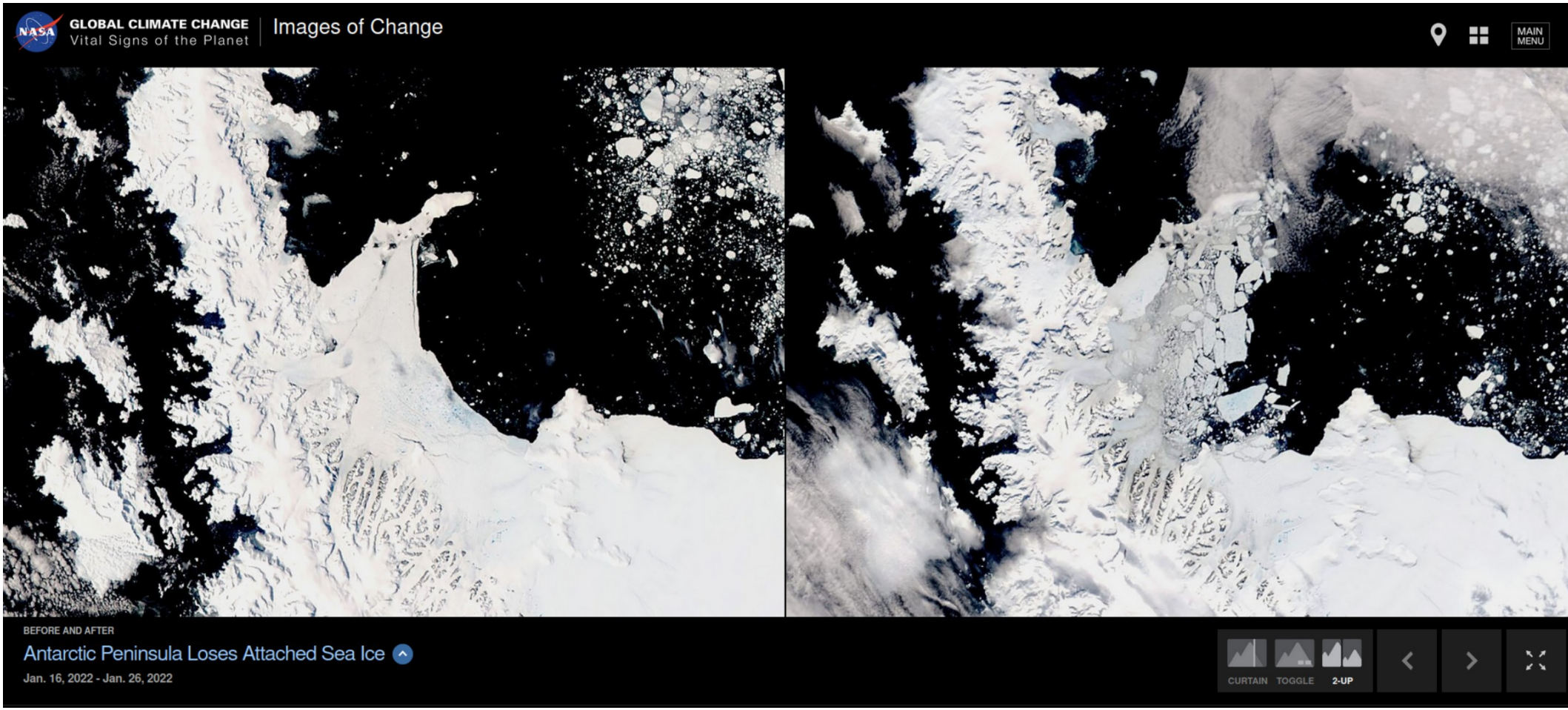
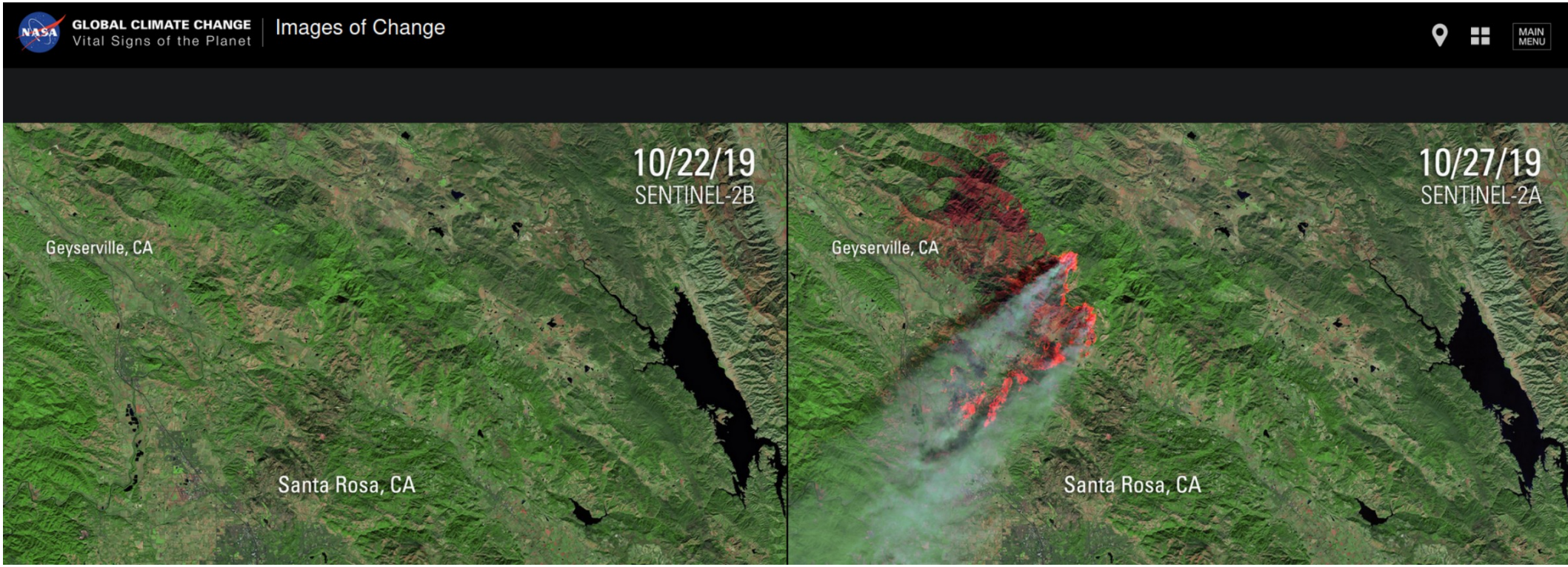
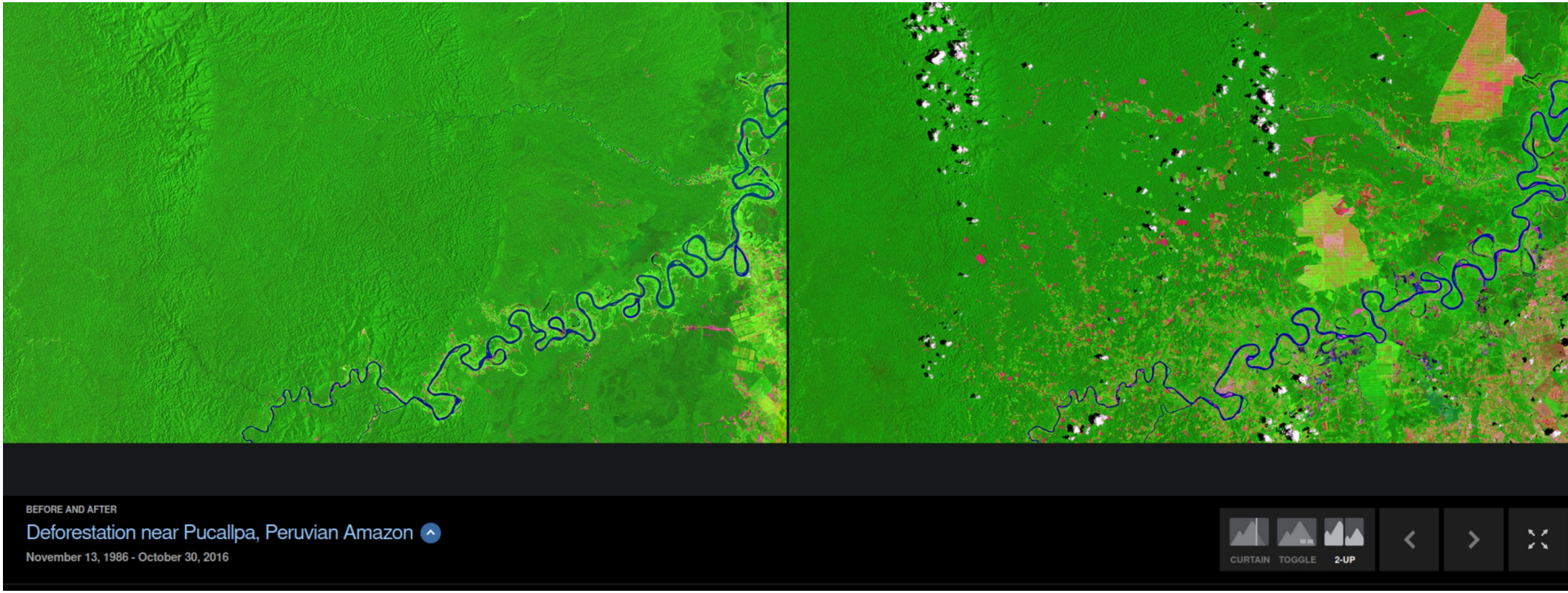


Detecting land cover and land cover change



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

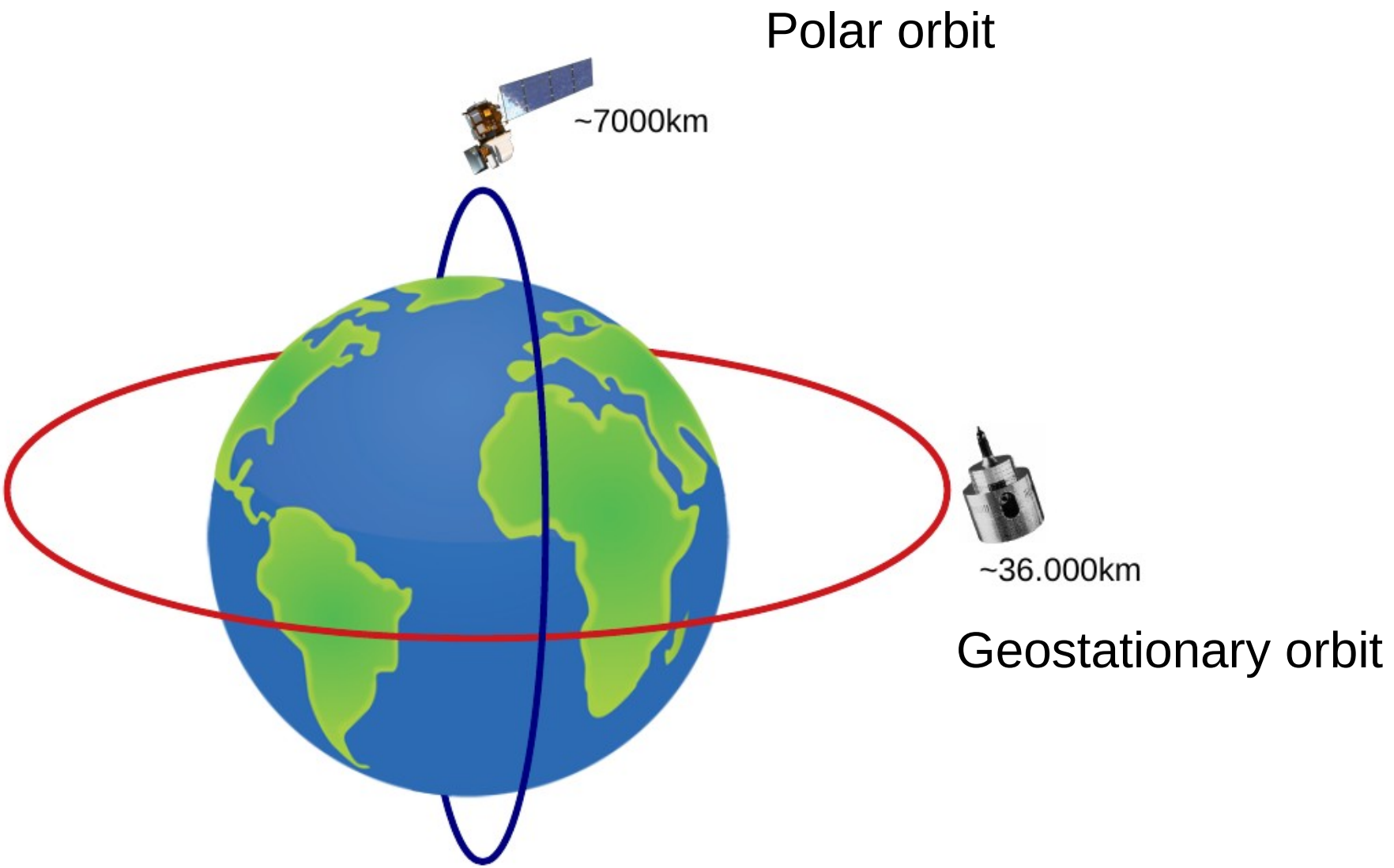
Which data to use? Spatial resolution

Aerial image (Google Earth): <1m

Landsat-scale: 30m

MODIS-scale: 500m

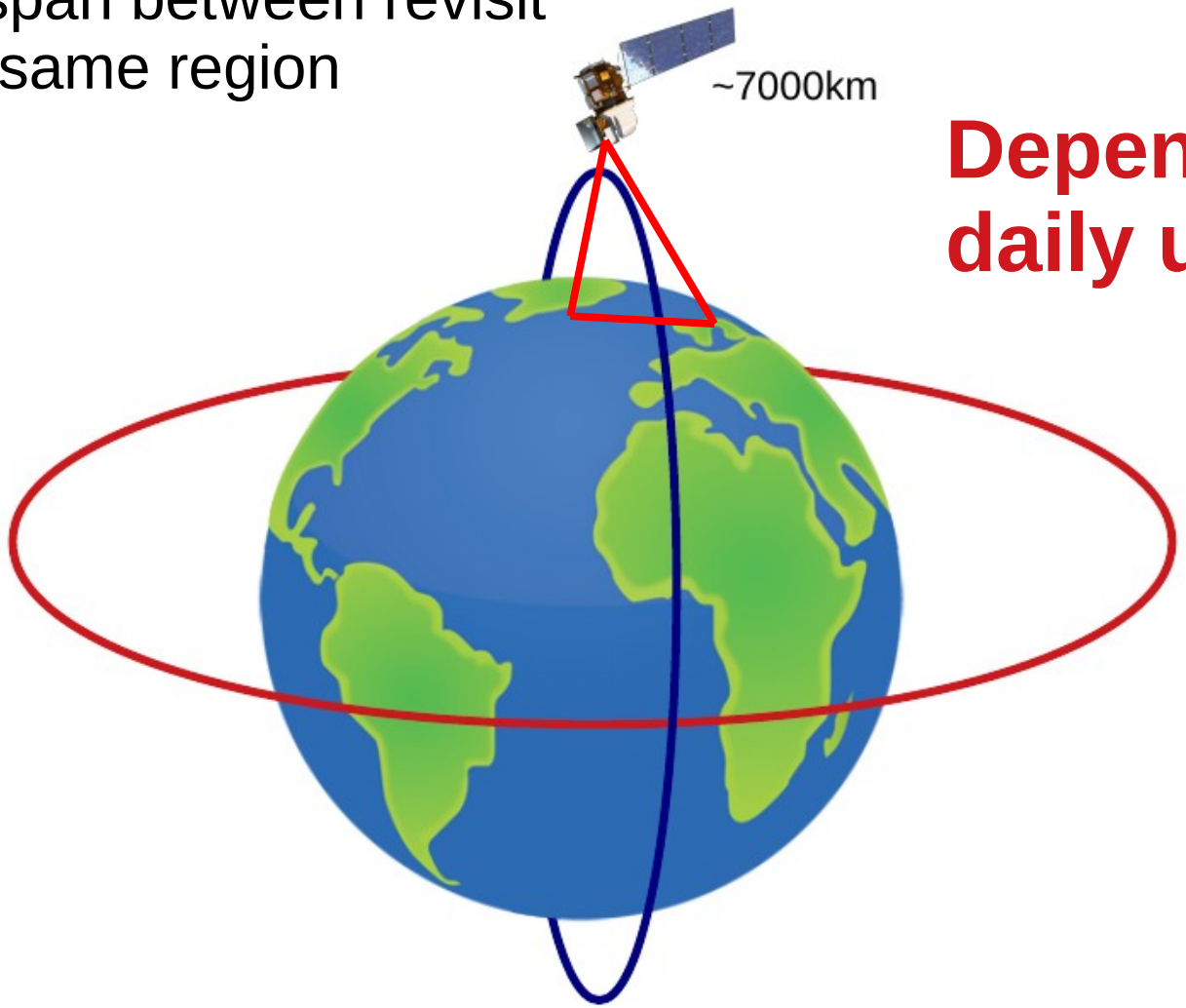
Which data to use? Temporal resolution



Which data to use? Temporal resolution

Time span between revisit of the same region

Polar orbit



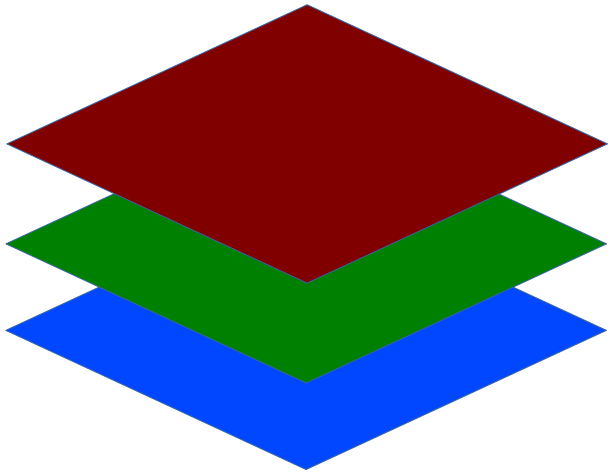
Depending on Swath. daily up to ~14 days

Geostationary orbit

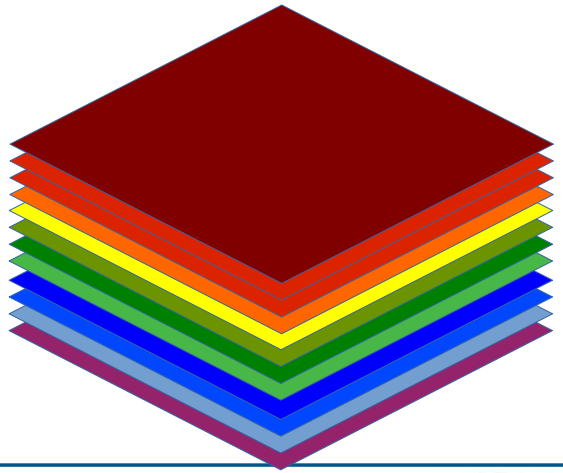
ca. 15 min

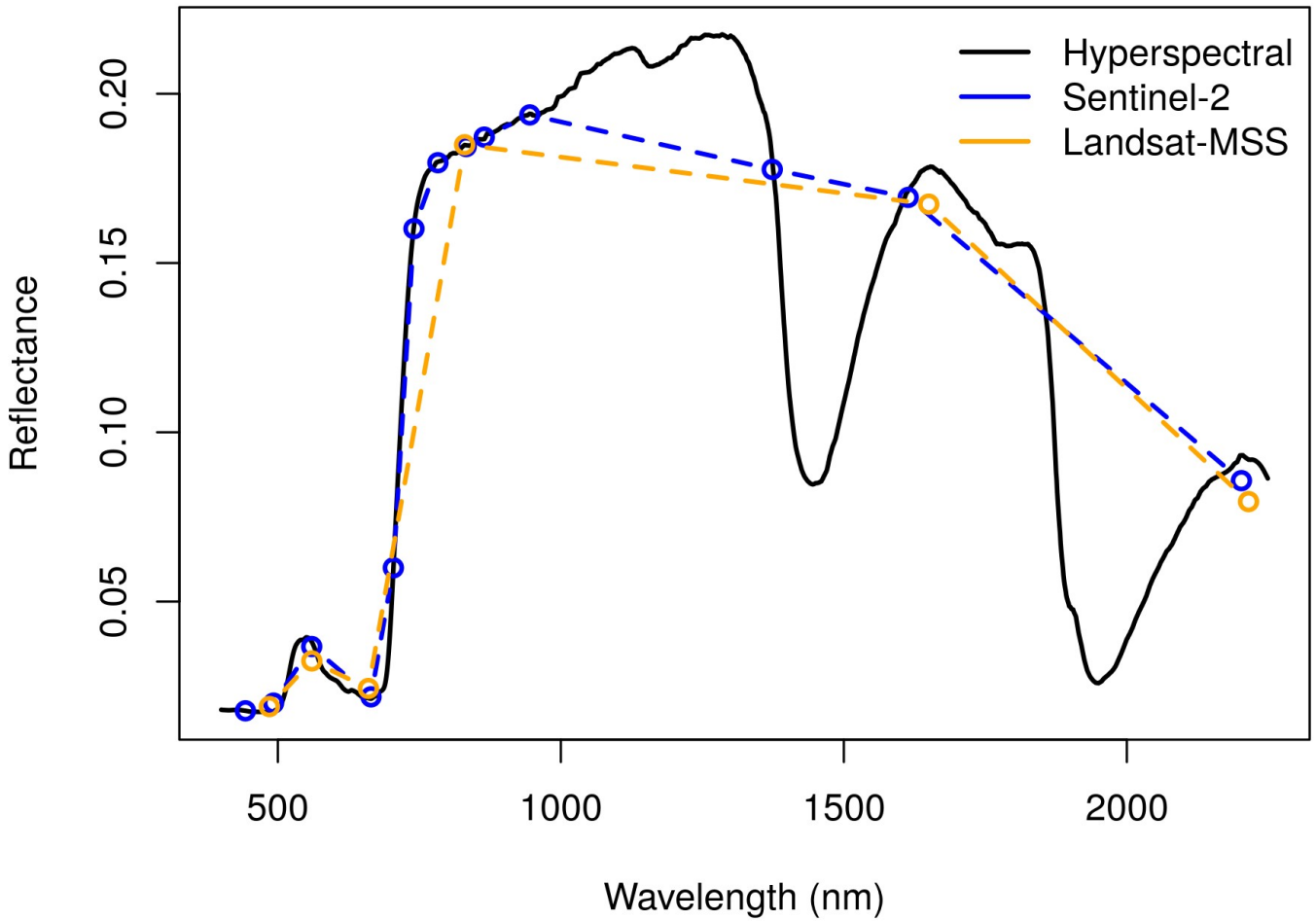
Which data to use? Spectral resolution

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

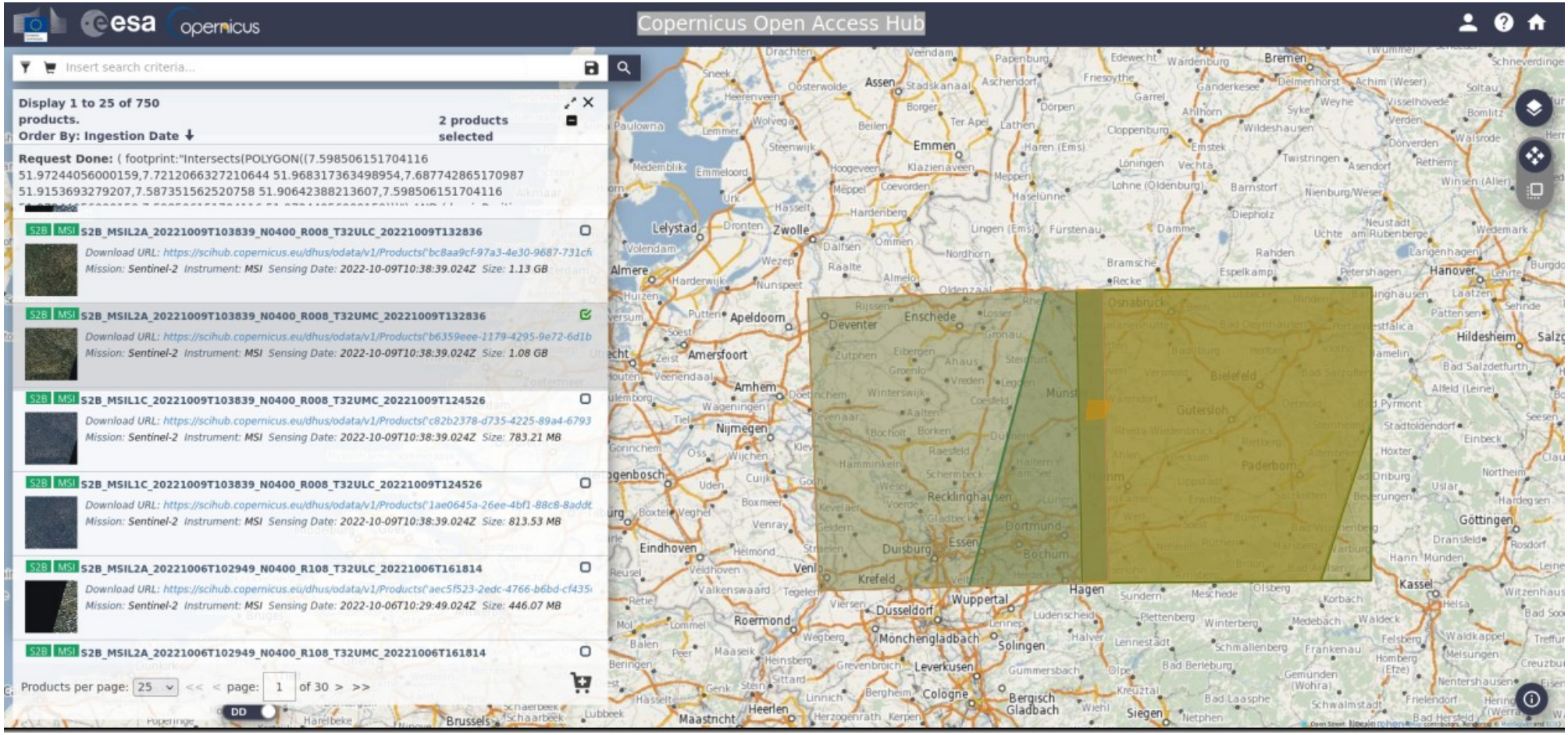
https://en.wikipedia.org/wiki/Sentinel-2

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

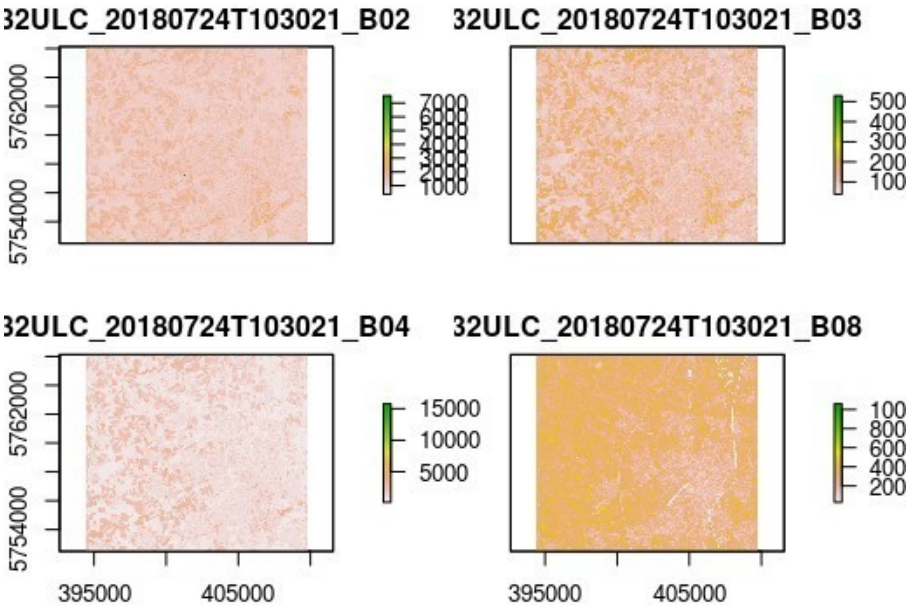


Load satellite data in R

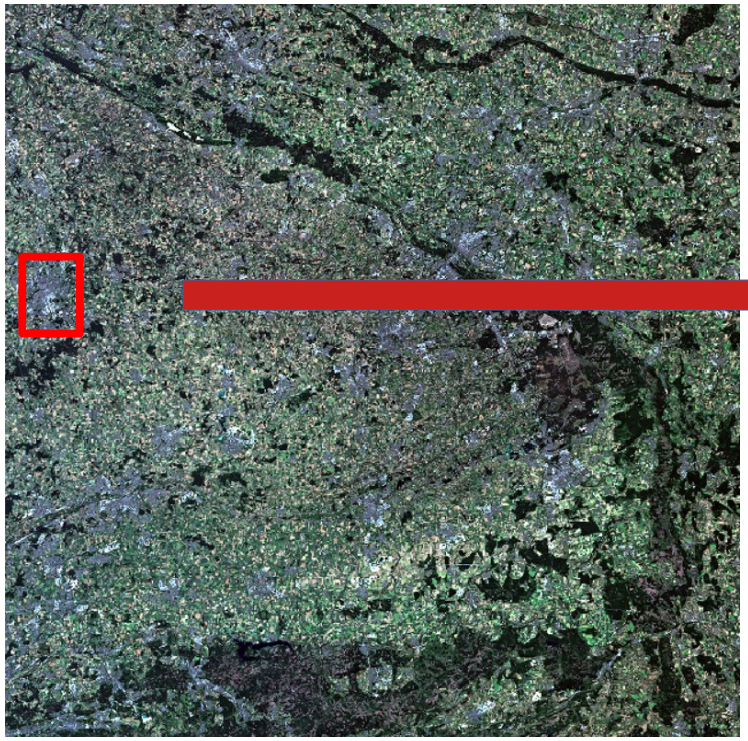
- Load the channels red,green,blue,NIR into R
- Load the 20m resolution channels as well and resample to 10m

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)

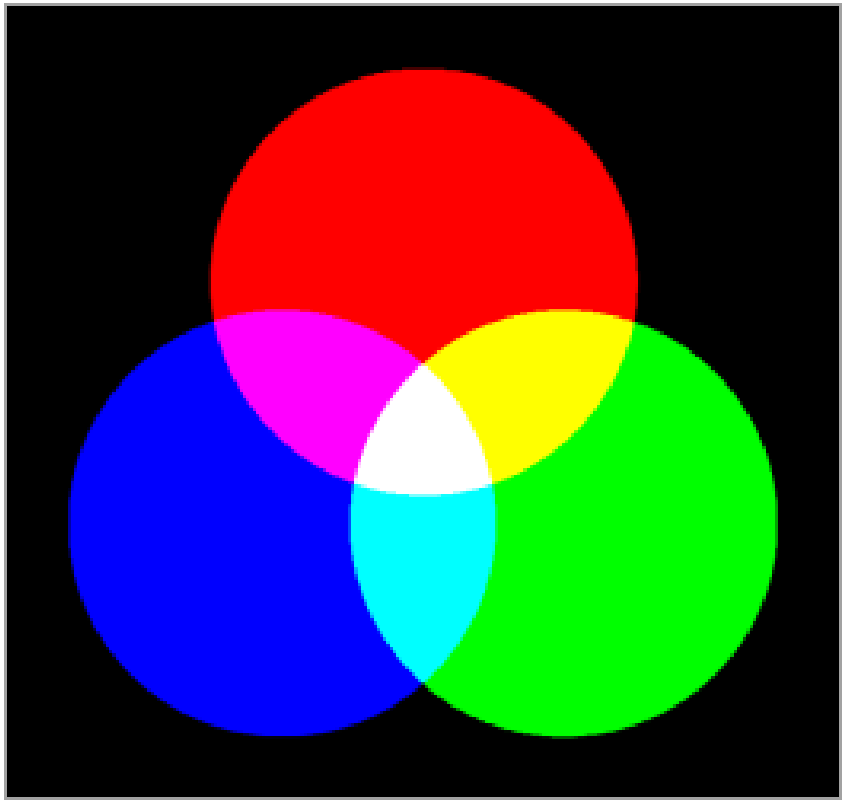
Crop the data

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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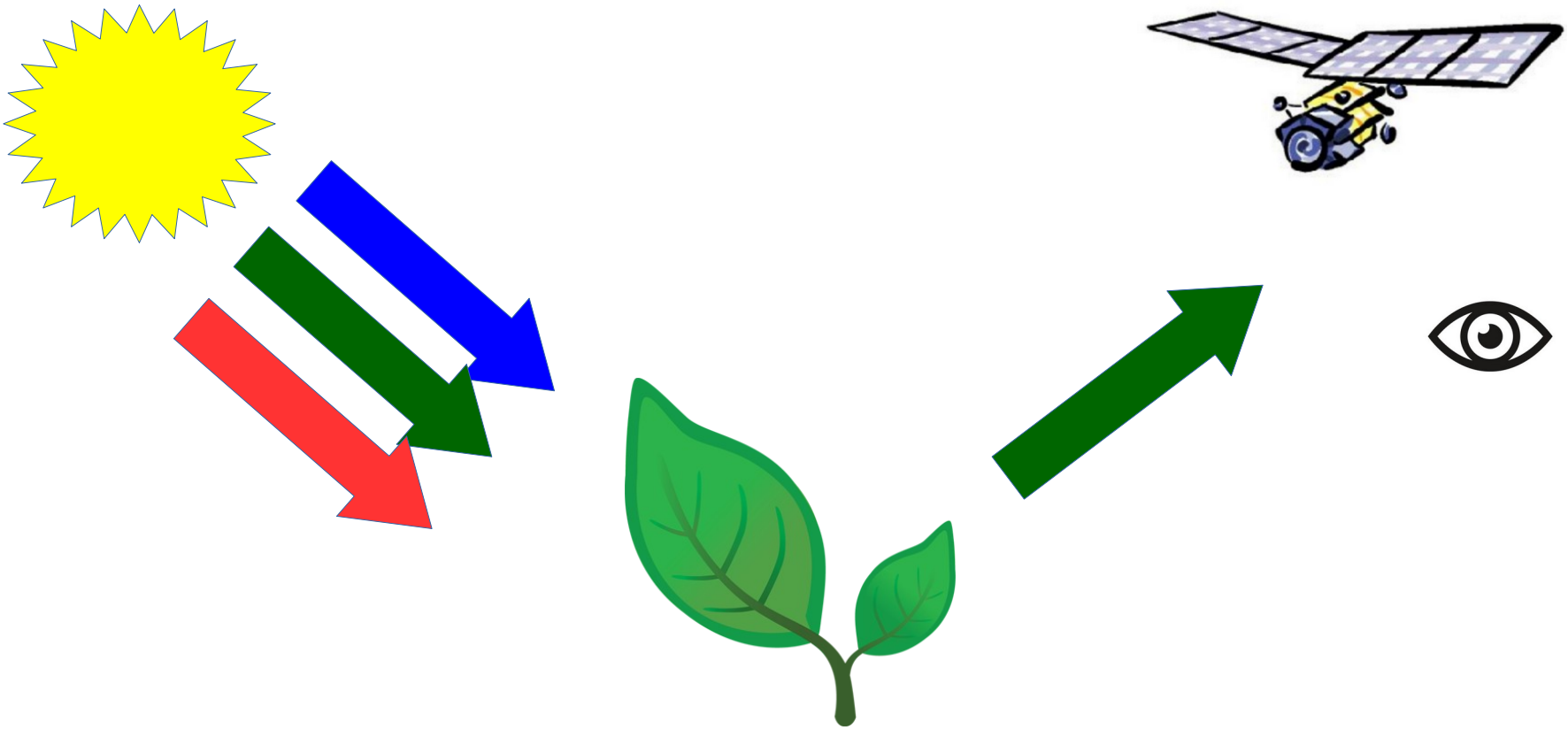

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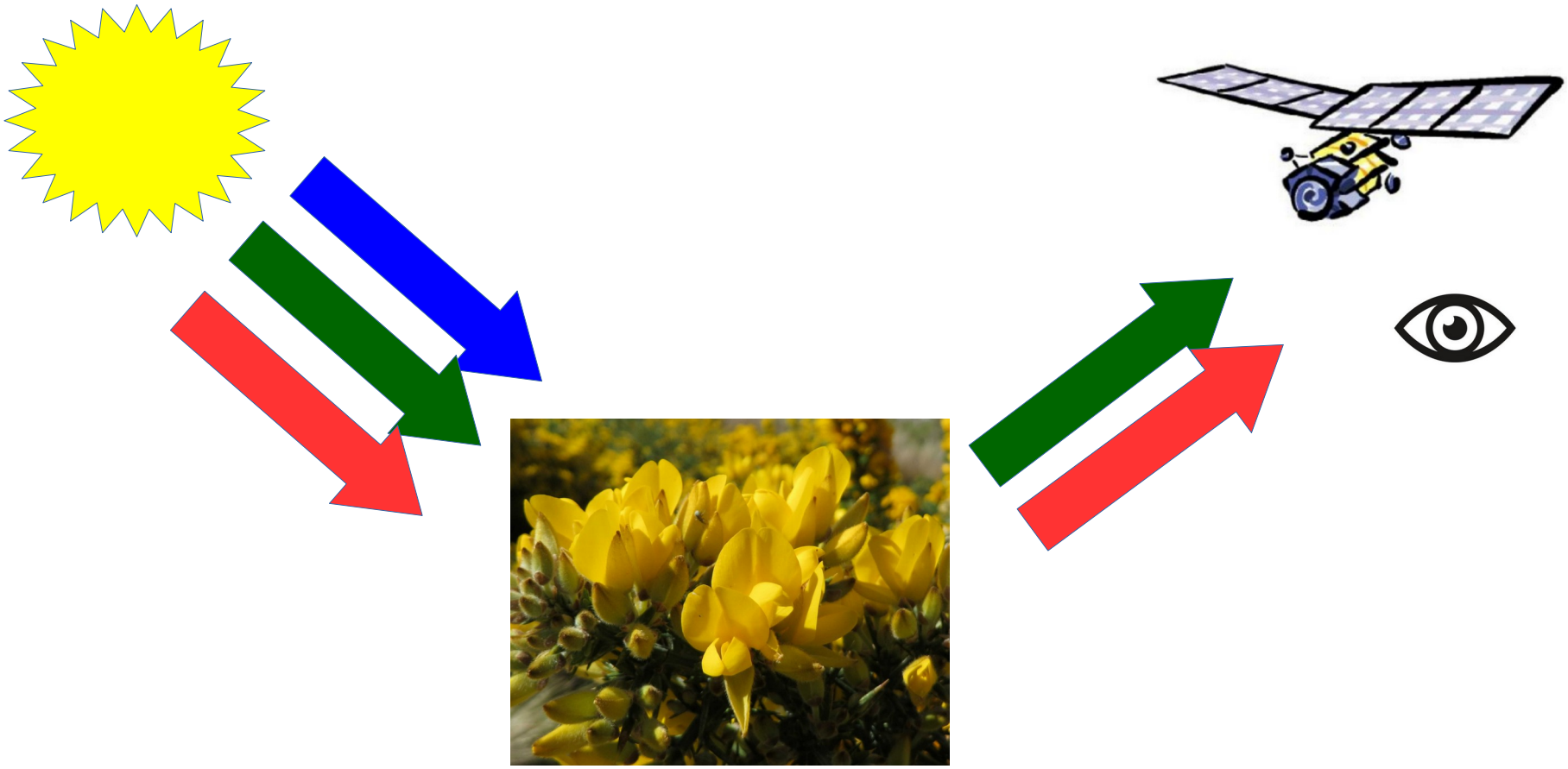

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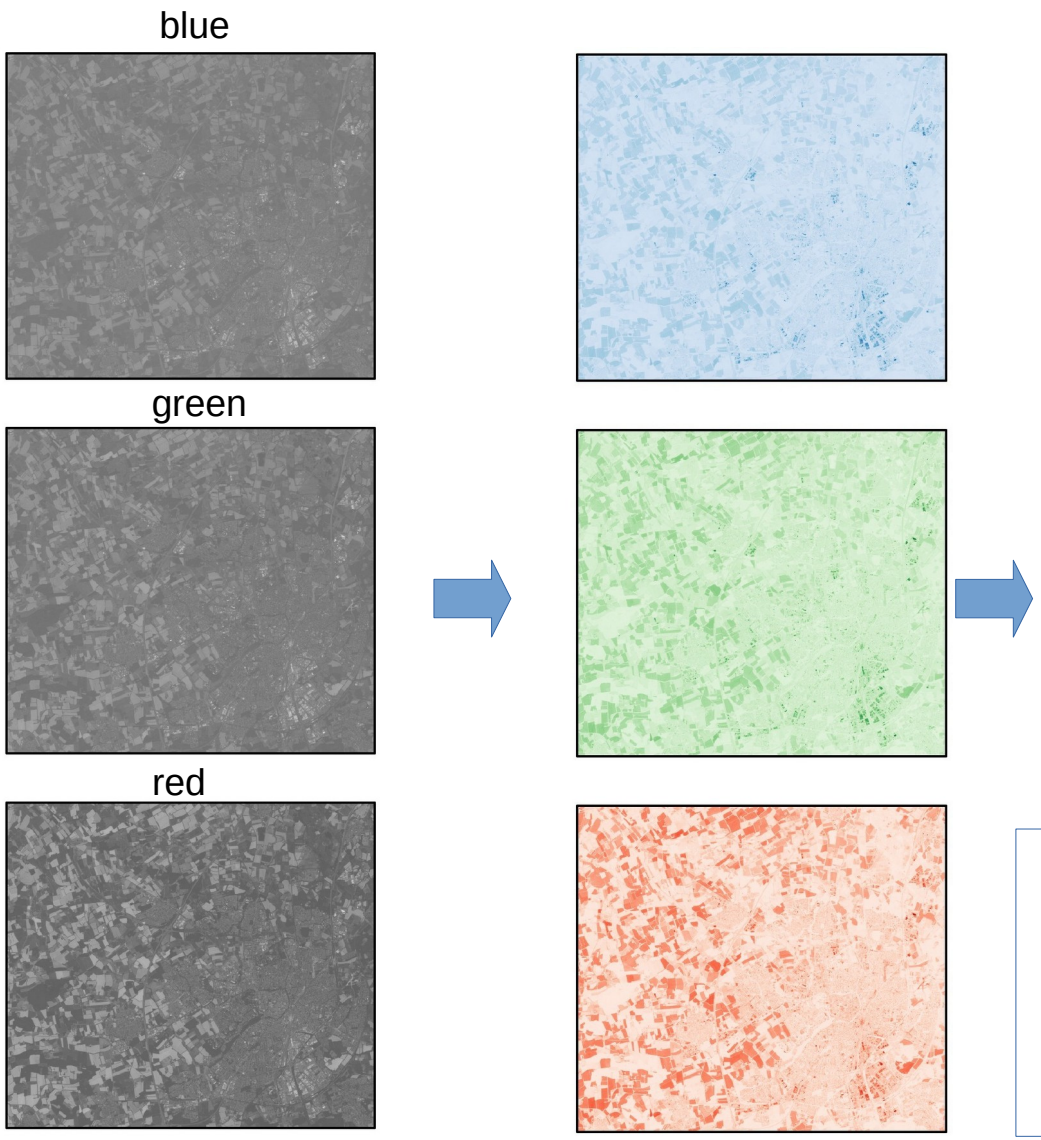


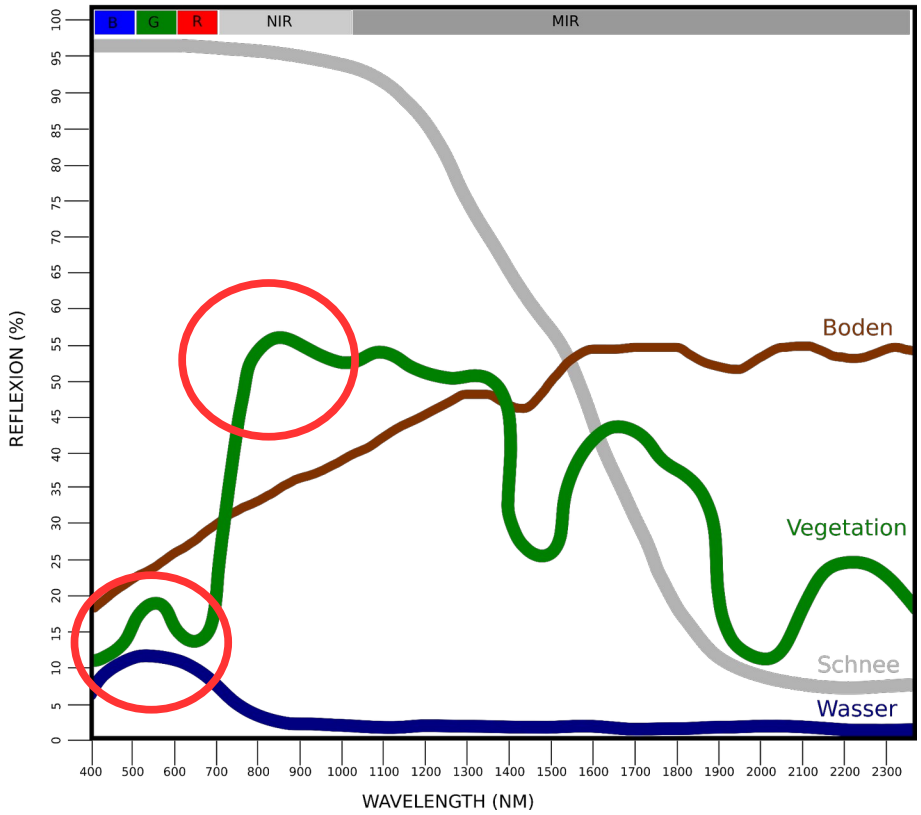
How to do a color composite in R

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

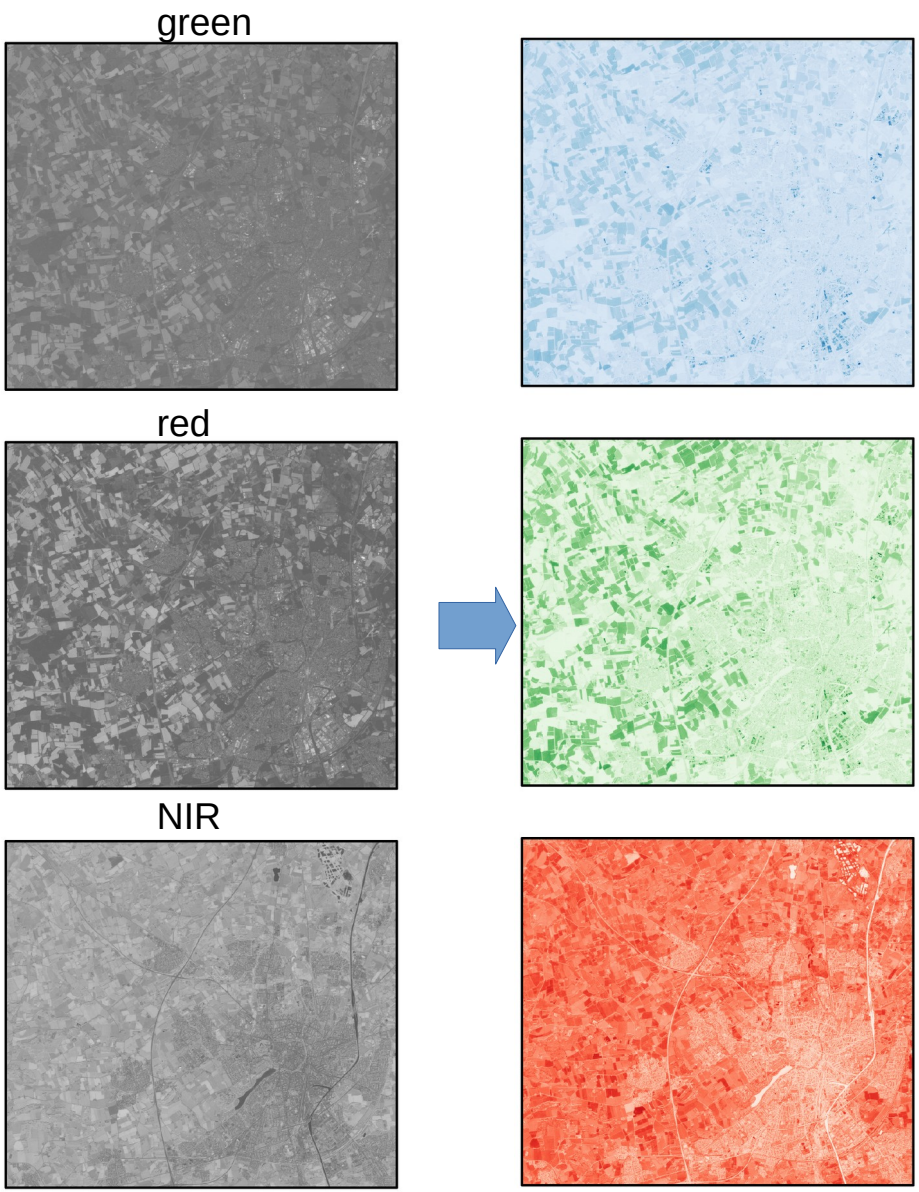
Artificial lawn or real grass?

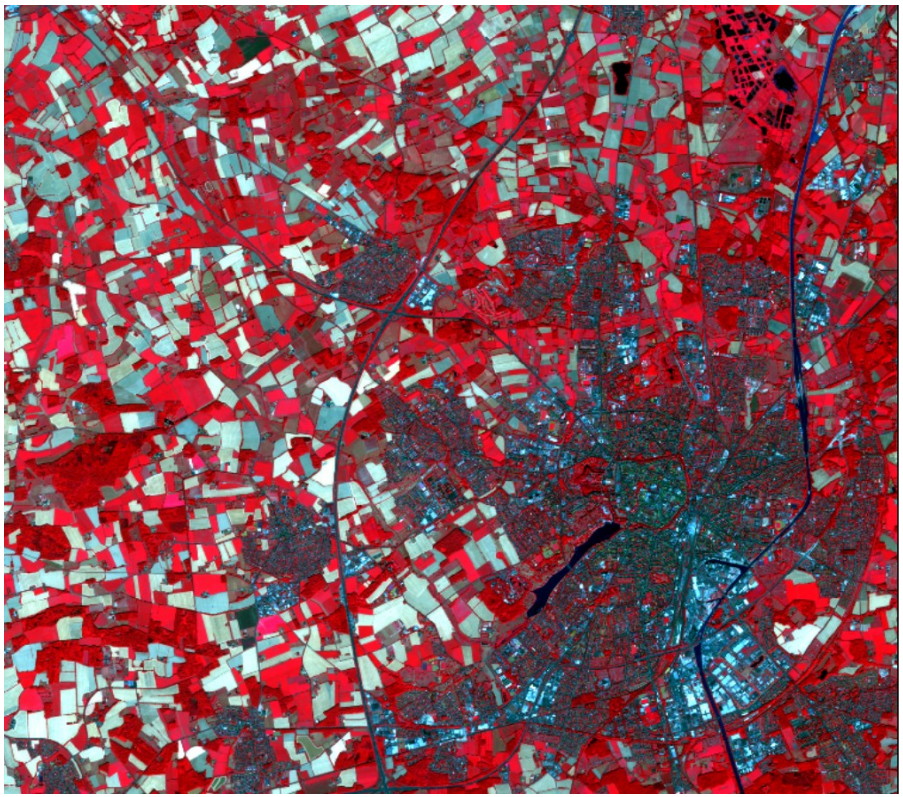
Marburg Uni-Stadion

Marburg Gaßmann-Stadion



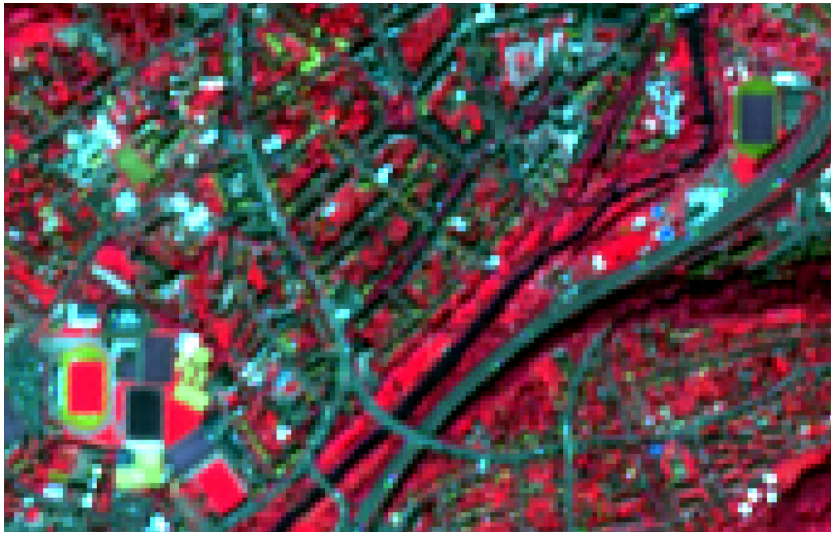
False color composite





Artificial lawn or real grass?

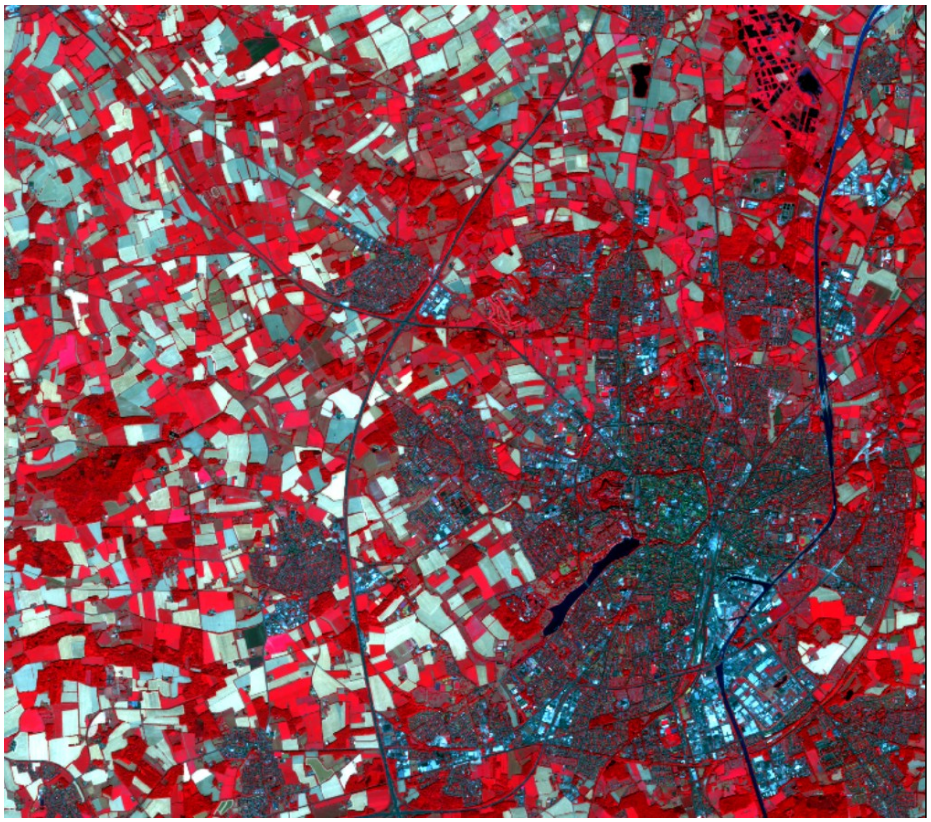
Marburg Uni-Stadion



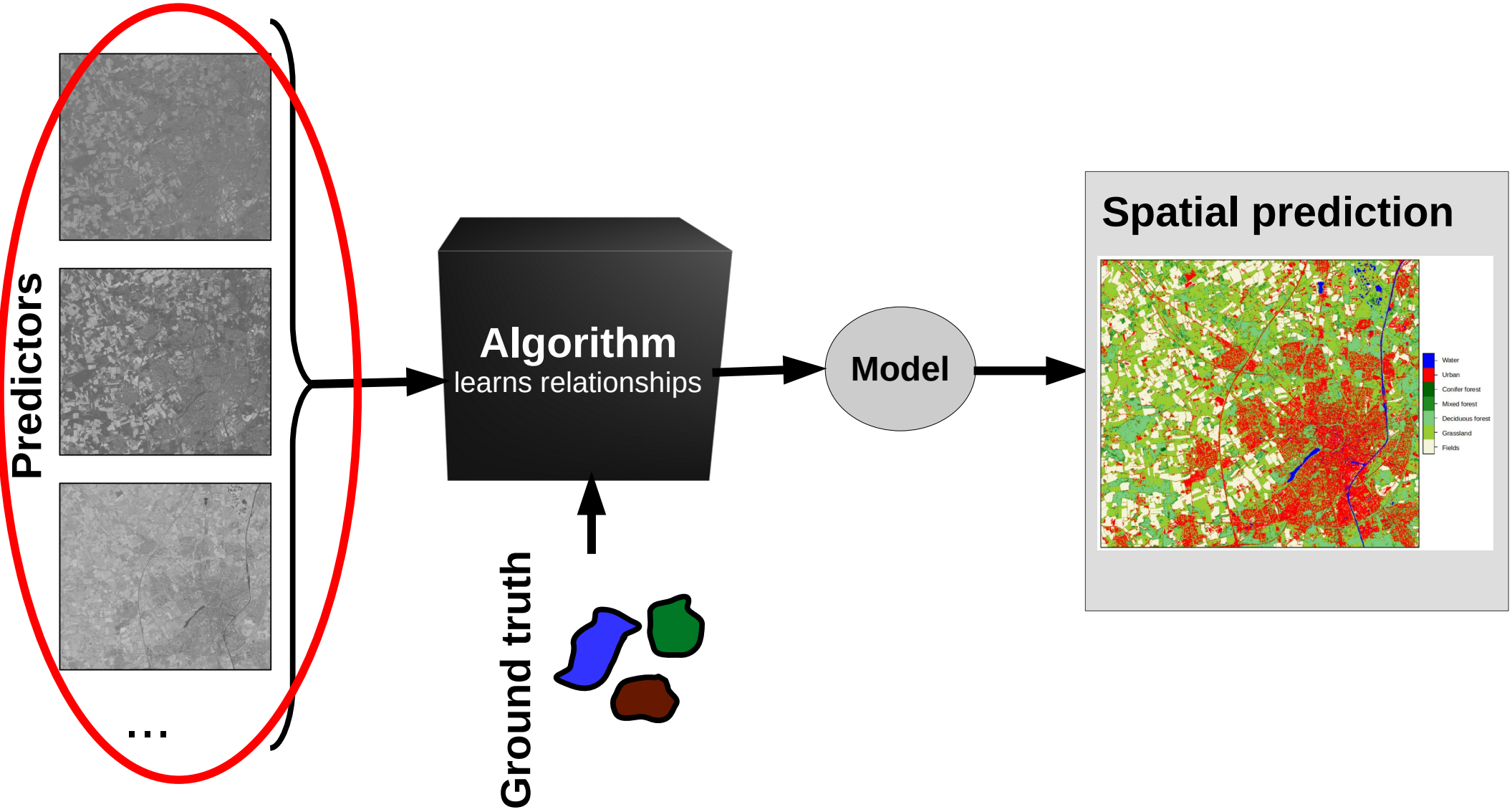
Marburg Gaßmann-Stadion

Task

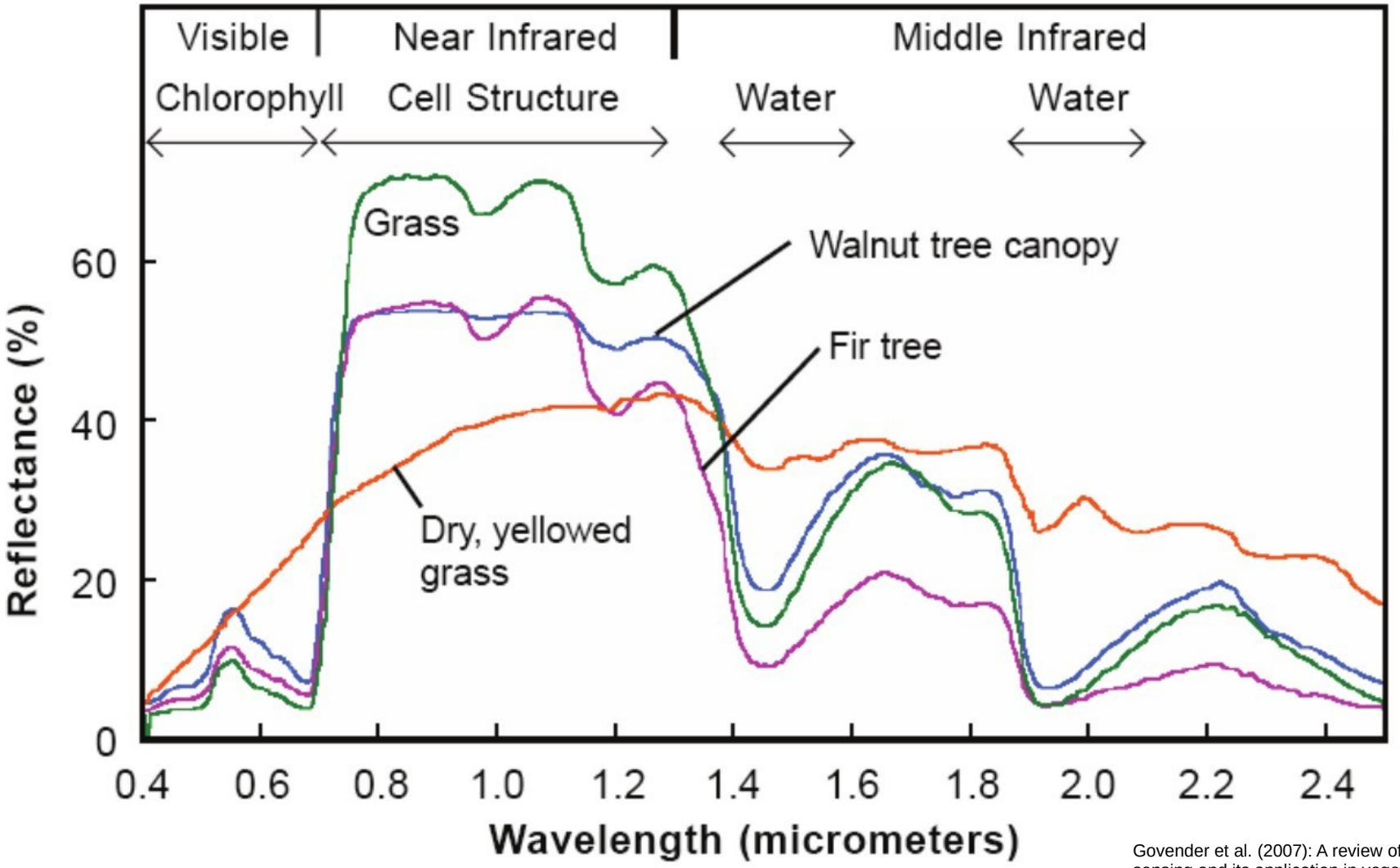
Visualize your image with a true color and a false color composite



Satellite-based predictors for land cover

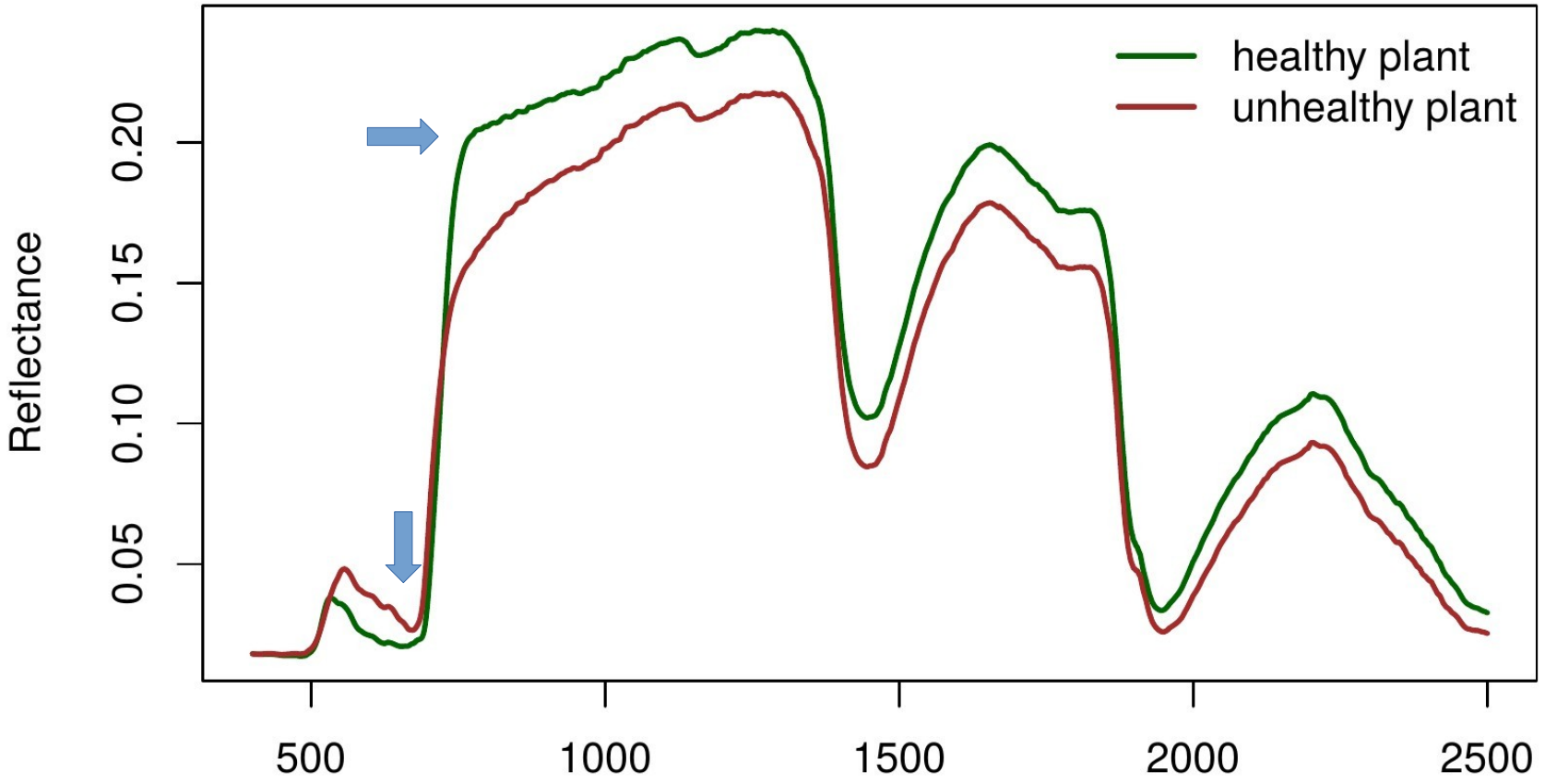


Further predictors: vegetation indices



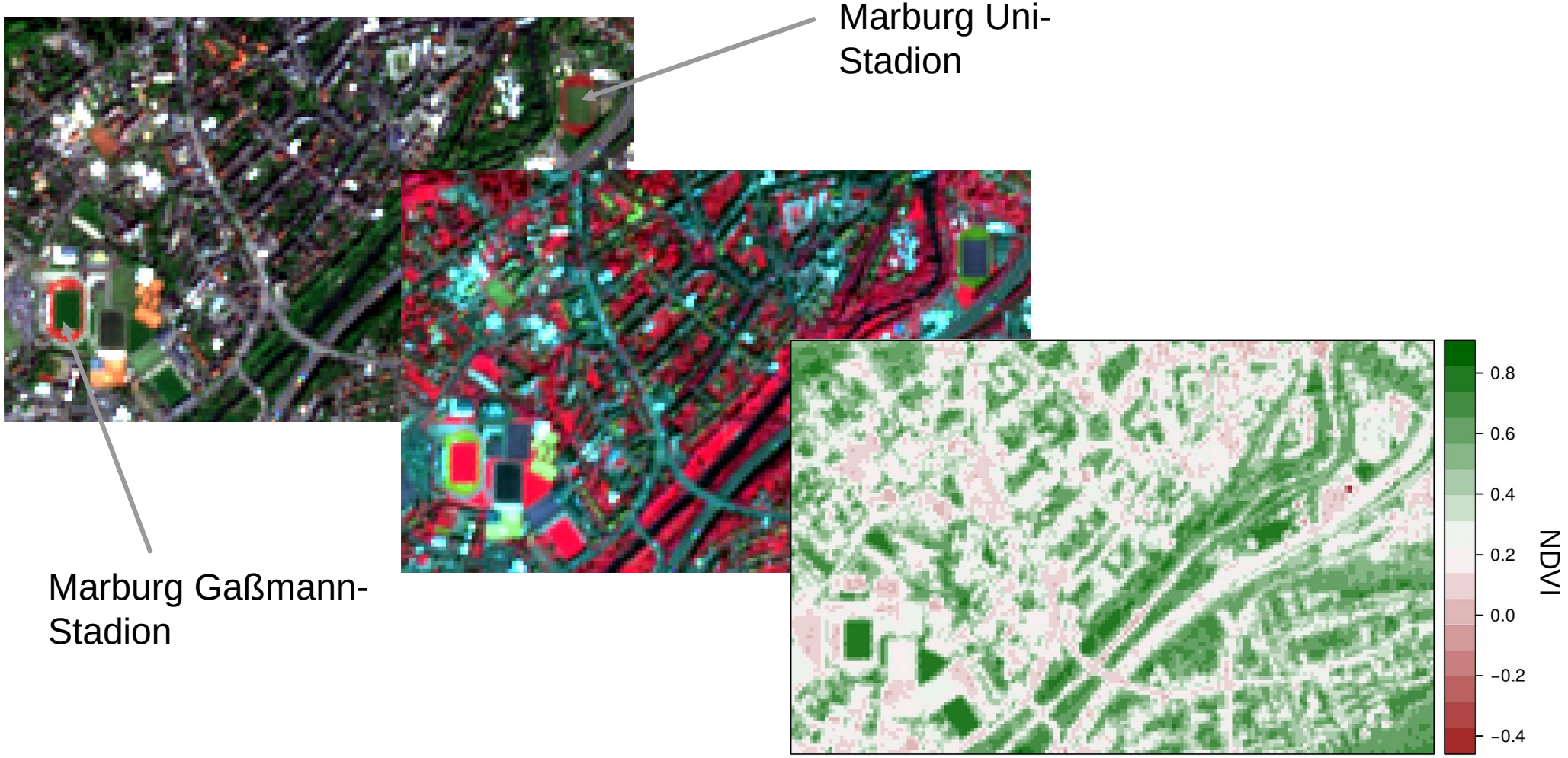
Govender et al. (2007): A review of hyperspectral remote sensing and its application in vegetation and water resource studies. Water S.A 33(2)

Further predictors: vegetation indices



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

Further predictors: vegetation indices



Further predictors: vegetation indices

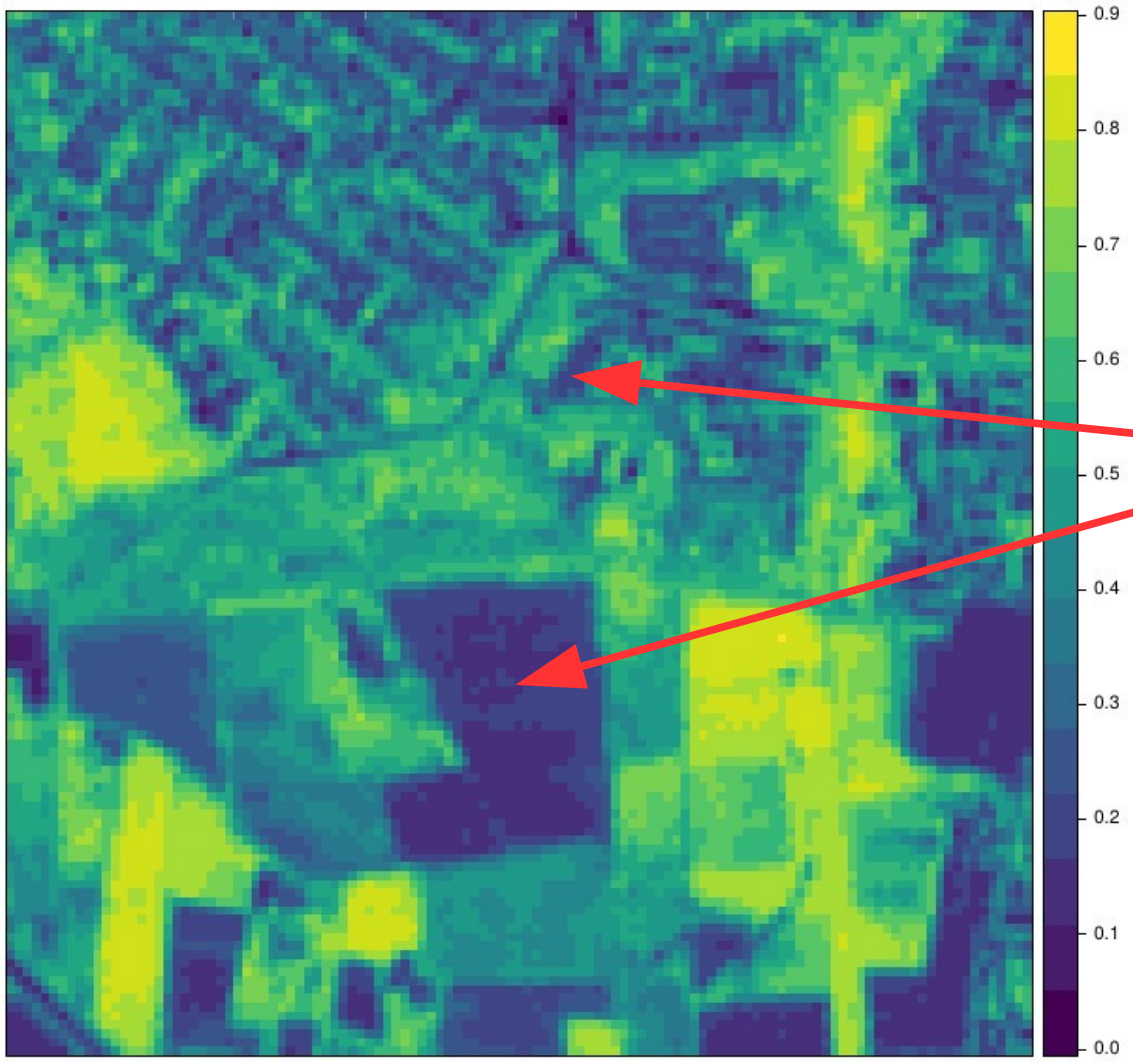
Calculate the NDVI of the satellite scene

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

Other suggestion for predictors: Texture

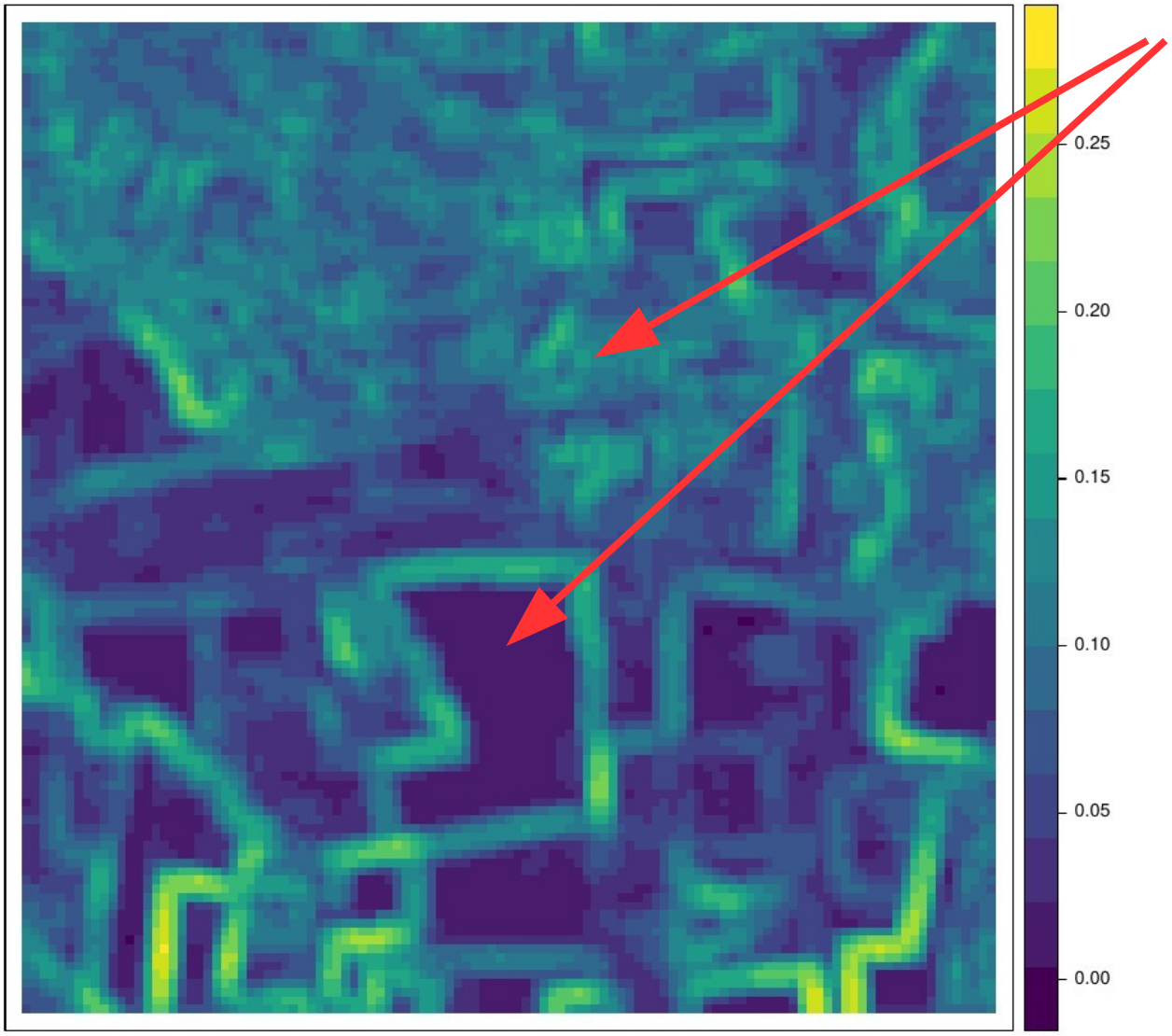
Very similar spectral properties

Other suggestion for predictors: Texture



...even in the NDVI

Other suggestion for predictors: Texture



Standard deviation of the NDVI

Calculation in a 3x3 Pixel Environment:

9	14	23
18	7	12
11	4	8

Mean= 11.7
SD=5.8

12	11	12
12	10	12
11	12	13

Mean= 11.7
SD=1.3

Other suggestion for predictors: Texture

Calculate Standard deviations of the NDVI in a defined pixel environment

Compile predictors

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