

# Land Monitoring by Advanced Earth Observation

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LBRAT2104 – 2020-21

*Professors*

Pr. Pierre Defourny

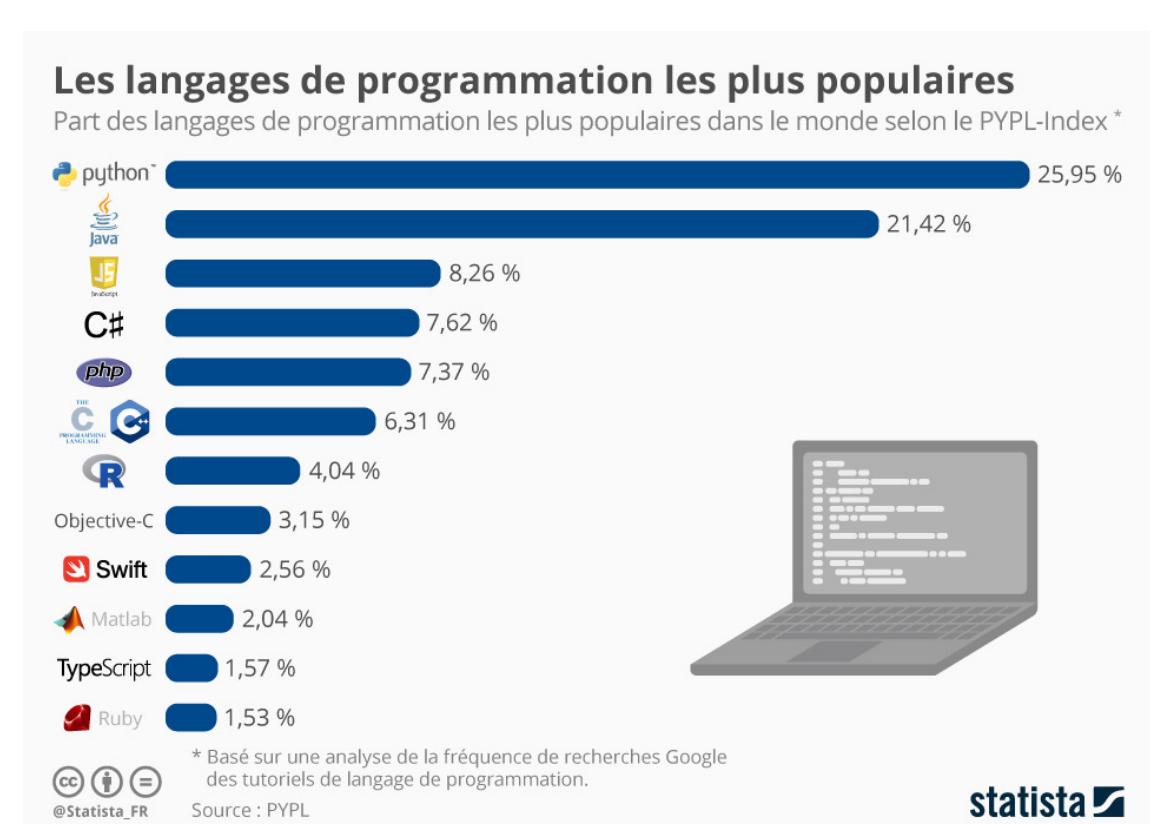
Dr. Sophie Bontemps

*Teaching assistant*

Nicolas Deffense

# Objectives

- Achieve the entire processing chain from raw satellite images to meaningful results
- Learn new geoprocessing **Python** libraries
- Timeseries analyses
- Change detection
- Quality control
- Biophysical variable retrieval (NDVI, LAI, ...)
- Classification with Machine Learning
- Validation & accuracy
- ...



# Disk management



Location	Capacity	Type	Read	Write
C:/	365GB	Local	YES	YES
Z:/LBRAT2104/	1GB / student	OASIS	YES	YES
Y:/AGRO/LBRAT2104/	256GB (9GB free)	OASIS	YES	NO
X:/LBRAT2104/	512GB	Remote	YES	YES

***When you log out of your session, all data on disk “C:” is deleted !***

***We will work exclusively on disk “X:”***

## Create an Anaconda Environment with Python 3.7

Numpy	1.19.2
Pandas	1.2.2
Geopandas	0.8.1
Rasterio	1.1.0
Matplotlib	3.3.4



# Jupyter Notebooks accessible in GitHub



*Git is a free and open-source distributed version control system designed to handle everything from small to very large projects with speed and efficiency.*

If you want to be sure to get the last version of the Jupyter notebooks, download them from my GitHub repository!  
All you need is an internet connection.

<https://github.com/nicolasdeffense/eo-toolbox/tree/main/notebooks>

You can also open HTML version of the notebooks to have a better view (but you cannot launch code in that way!)

[https://nicolasdeffense.github.io/eo-toolbox/notebooks/geopandas\\_basics.html](https://nicolasdeffense.github.io/eo-toolbox/notebooks/geopandas_basics.html)

[https://nicolasdeffense.github.io/eo-toolbox/notebooks/sentinel\\_2\\_prepro.html](https://nicolasdeffense.github.io/eo-toolbox/notebooks/sentinel_2_prepro.html)

[https://nicolasdeffense.github.io/eo-toolbox/notebooks/loops\\_multiple\\_images.html](https://nicolasdeffense.github.io/eo-toolbox/notebooks/loops_multiple_images.html)

[https://nicolasdeffense.github.io/eo-toolbox/notebooks/in\\_situ\\_sampling\\_design.html](https://nicolasdeffense.github.io/eo-toolbox/notebooks/in_situ_sampling_design.html)

[https://nicolasdeffense.github.io/eo-toolbox/notebooks/random\\_forest\\_classification.html](https://nicolasdeffense.github.io/eo-toolbox/notebooks/random_forest_classification.html)

# Activate an environment with command line

## 0. Open “DS-5 v5.29.1 Command Prompt”

### 1. Create Anaconda environment on disk X      *!\\ already done /\\*

```
conda create -p X:/anaconda_env/LBRAT2104_env_ndeffense  
python=3.7 numpy=1.19.2 pandas=1.1.5 geopandas=0.8.1  
rasterio=1.1.0 rasterstats=0.14.0 matplotlib=3.3.2 scipy=1.5.2
```

### 2. Go to disk X

X:

### 3. Activate environment

```
conda activate /anaconda_env/LBRAT2104_env_ndeffense
```

### 4. Launch Jupyter Notebook

jupyter notebook

### 5. Close Jupyter Notebook

CTRL-C

CTRL-C

A high-resolution satellite image showing the urban area of Louvain-la-Neuve, Belgium, surrounded by agricultural fields. The image captures various buildings, roads, and green spaces from an aerial perspective.

Download a  
satellite image

Louvain-la-Neuve, 31/07/2020  
Sentinel2B – MSI – L2A

Land Monitoring by Advanced Earth Observation

# Copernicus Open Access Hub

<https://scihub.copernicus.eu/>

Access to all Sentinel missions  
data through the interactive  
Graphical User Interface



Welcome to the Copernicus Open Access Hub

The Copernicus Open Access Hub (previously known as Sentinels Scientific Data Hub) provides complete, free and open access to [Sentinel-1](#), [Sentinel-2](#), [Sentinel-3](#) and [Sentinel-5P](#) user products, starting from the In-Orbit Commissioning Review (IOCR).

Sentinel Data are also available via the Copernicus Data and Information Access Services (DIAS) through several [platforms](#).

Please visit our [User Guide](#) for getting started with the Data Hub Interface. Discover how to use the APIs and create scripts for automatic search and download of Sentinels' data.

Latest update: see the section on [Long Term Archive](#) for the upgrade of the interfaces for access to offline data.

For further details or requests of support please send an e-mail to [eosupport@copernicus.esa.int](mailto:eosupport@copernicus.esa.int)

Reports & Stats

Data updated hourly

32,417 prod. published in the last 24h (S1 + S2 + S3 + S5P)

219,835 downloads in the last 24h (SciHub + API Hub + S-3 PreOps + S-5P PreOps)

Reports

Resources

Open Hub

API Hub

S-5P Pre-Ops

POD Hub

# Create an account

The screenshot shows the Copernicus Open Access Hub interface. At the top, there are logos for European Commission, esa, and Copernicus. A search bar with placeholder text "Insert search criteria..." and a magnifying glass icon is positioned above a map of Europe and the Middle East. The map displays various countries and their capital cities. To the right of the map, a login form is visible. It includes fields for "username" (containing "ndeffense") and "password" (containing "....."). Below these fields is a "LOGIN" button. To the right of the "LOGIN" button are links for "Sign up" (which is highlighted with a red box) and "Forgot password?". At the bottom of the page, there is a footer with the text "Land Monitoring by Advanced Earth Observation" and a small copyright notice.

Copernicus Open Access Hub

Please login to access our services...

ndeffense

.....

LOGIN

**Sign up** [Forgot password?](#)

Land Monitoring by Advanced Earth Observation

# Advanced Search

## Polarisation

- HH
- HV
- VV
- VH

## Mission

## Satellite Platform

- S2A / S1A
- S2B / S1B
- Both (leave empty)

Sensing period

» Sensing period  
2020/07/30  2020/08/01

» Ingestion period

Mission: Sentinel-1

Satellite Platform   
Polarisation   
Relative Orbit Number (from 1 to 175)

Mission: Sentinel-2

Satellite Platform   
Product Type S2MSI2A  
Cloud Cover % (e.g.[0 TO 9.4]) [0 TO 50]

- Product Type
- S2 MSI 1c
  - S2 MSI 2a
  - (S2 MSI 2ap)

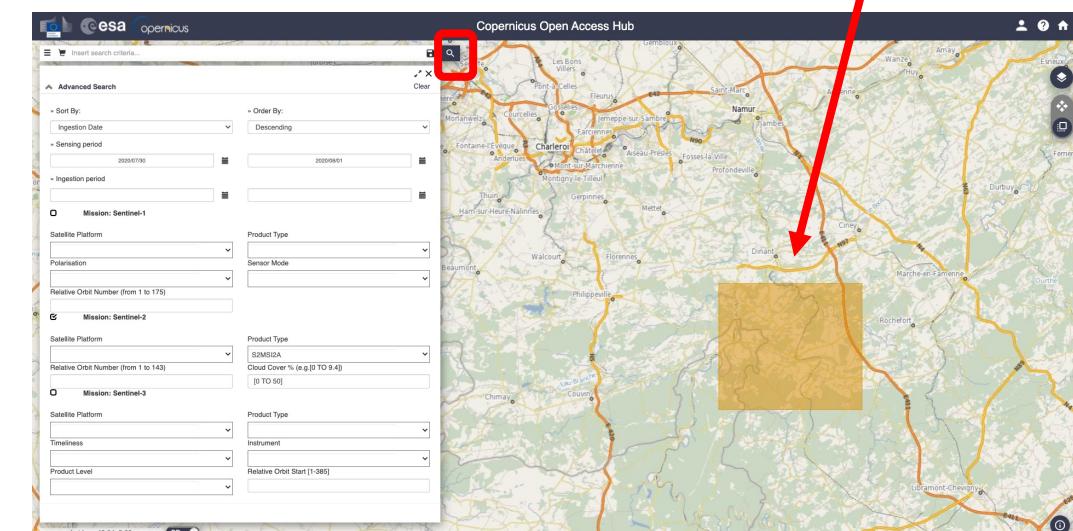
Land Monitoring by Advanced Earth Observation

## Product Type

- SLC
- GRD

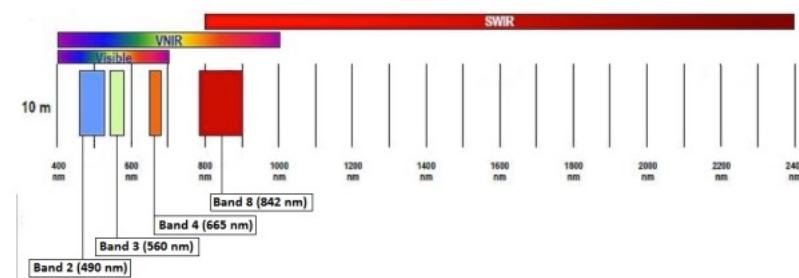
## Sensor Mode

- SM
- IW
- EW
- WV

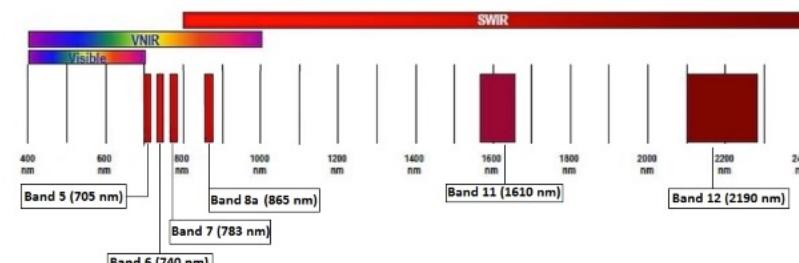


# Download image

## 10 metre spatial resolution:



## 20 metre spatial resolution:



The image shows the Copernicus Open Access Hub interface. A search dialog is open, displaying a single product selected. The request is for a polygon footprint intersecting a specific area. The download URL is provided: [https://scihub.copernicus.eu/dhus/odata/v1/Products\('e0a718d503656808820901,5.10646254126440850.03656808820901,5.10646254126440850.210821014A9216A782282293123038](https://scihub.copernicus.eu/dhus/odata/v1/Products('e0a718d503656808820901,5.10646254126440850.03656808820901,5.10646254126440850.210821014A9216A782282293123038)

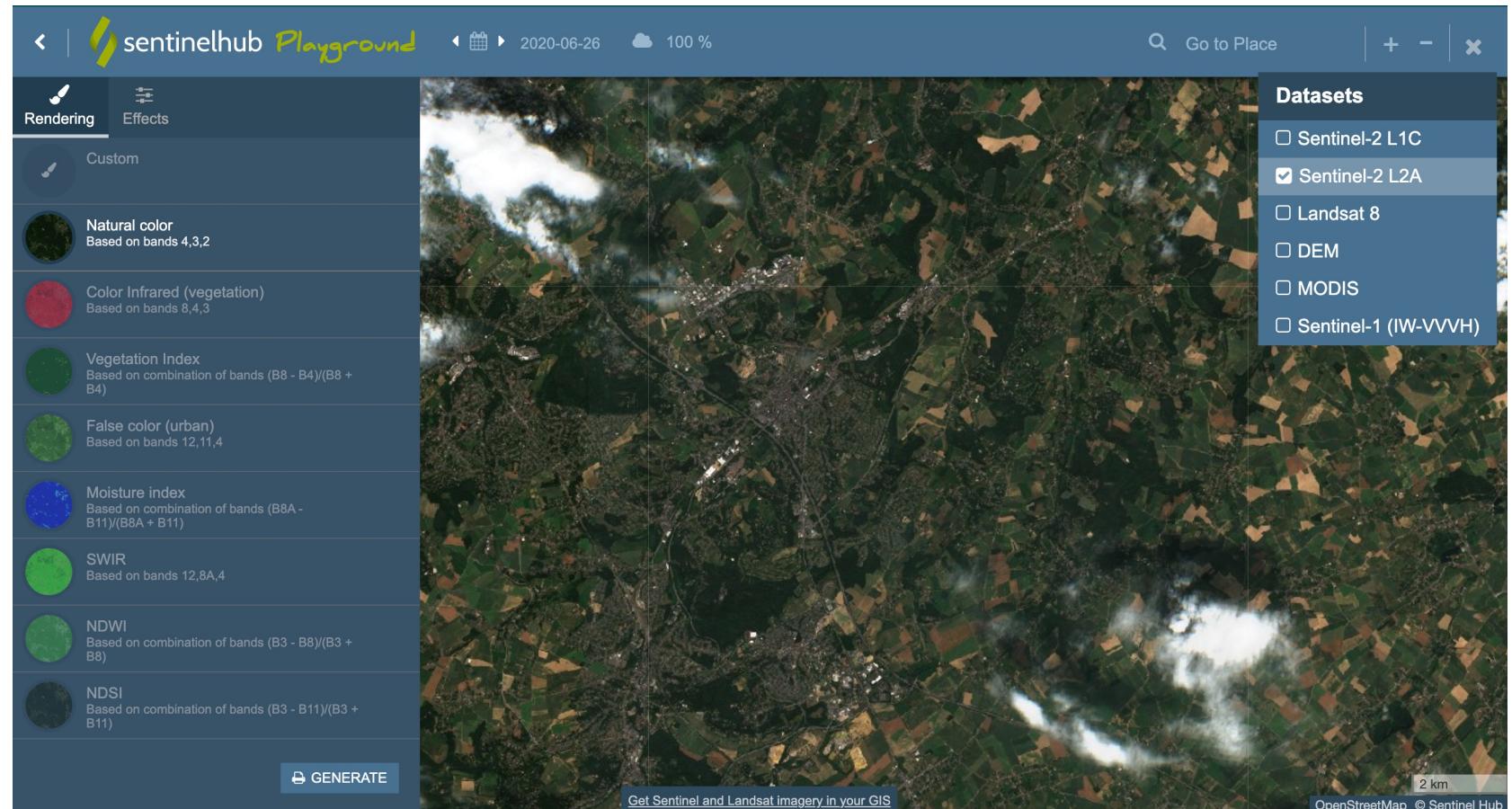
The map view shows a large orange polygon highlighting a region in Belgium and Luxembourg. A red box highlights the download button in the dialog. A large red text overlay at the bottom center of the map area reads: **/!\ ± 1,2 GB / S2 tile /!\\**.

S2B_MSIL2A...140558.SAFE	AUX_DATA	L2A_T31UFR...731T104607	AUX_DATA	R10m	T31UFR_20200731T103629_AOT_10m.jp2
	DATASTRIP		IMG_DATA	R20m	T31UFR_20200731T103629_B02_10m.jp2
	GRANULE		MTD_TL.xml	R60m	T31UFR_20200731T103629_B03_10m.jp2
	HTML		QI_DATA		T31UFR_20200731T103629_B04_10m.jp2
	INSPIRE.xml				T31UFR_20200731T103629_B08_10m.jp2
	manifest.safe				T31UFR_20200731T103629_TCI_10m.jp2
	MTD_MSIL2A.xml				T31UFR_20200731T103629_WVP_10m.jp2
	rep_info				

# Sentinel Playground

<https://www.sentinel-hub.com/explore/sentinelplayground/>

- Easy-to-use discovery
- Exploring of full-resolution Sentinel-1, Sentinel-2, Landsat 8, DEM and MODIS imagery
- Complete and daily updated Sentinel-2 archive



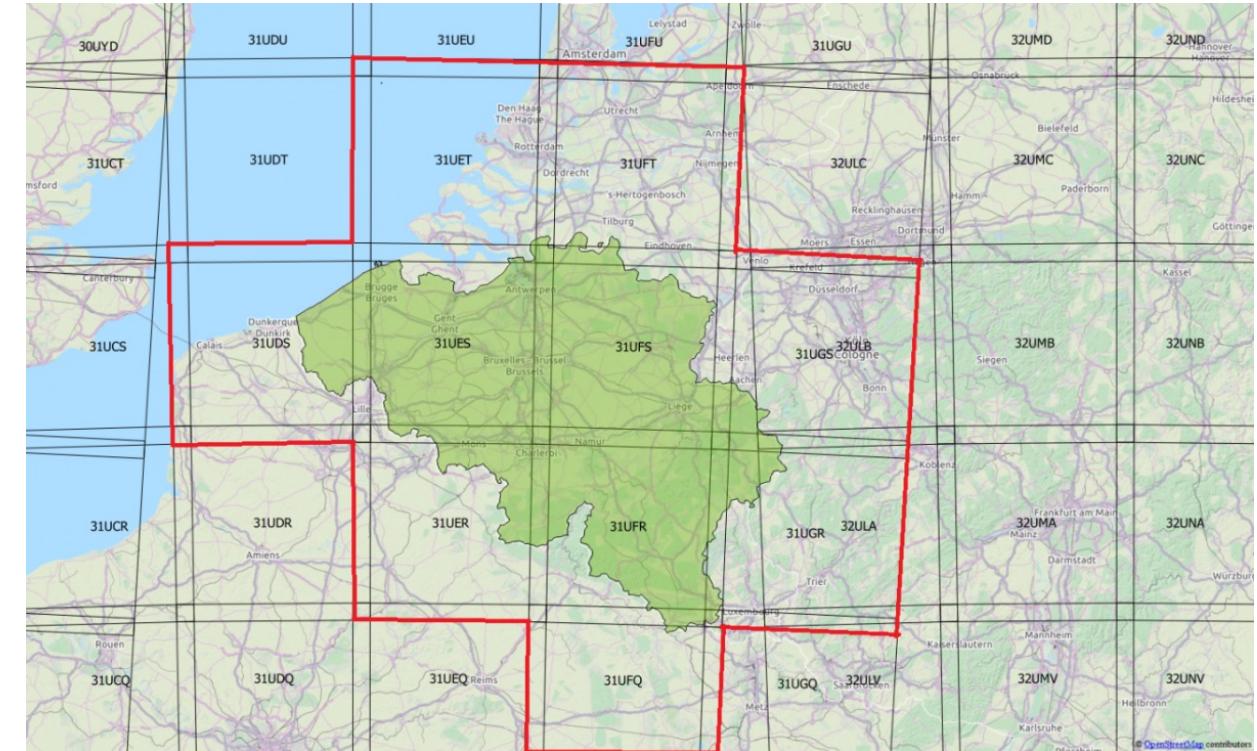
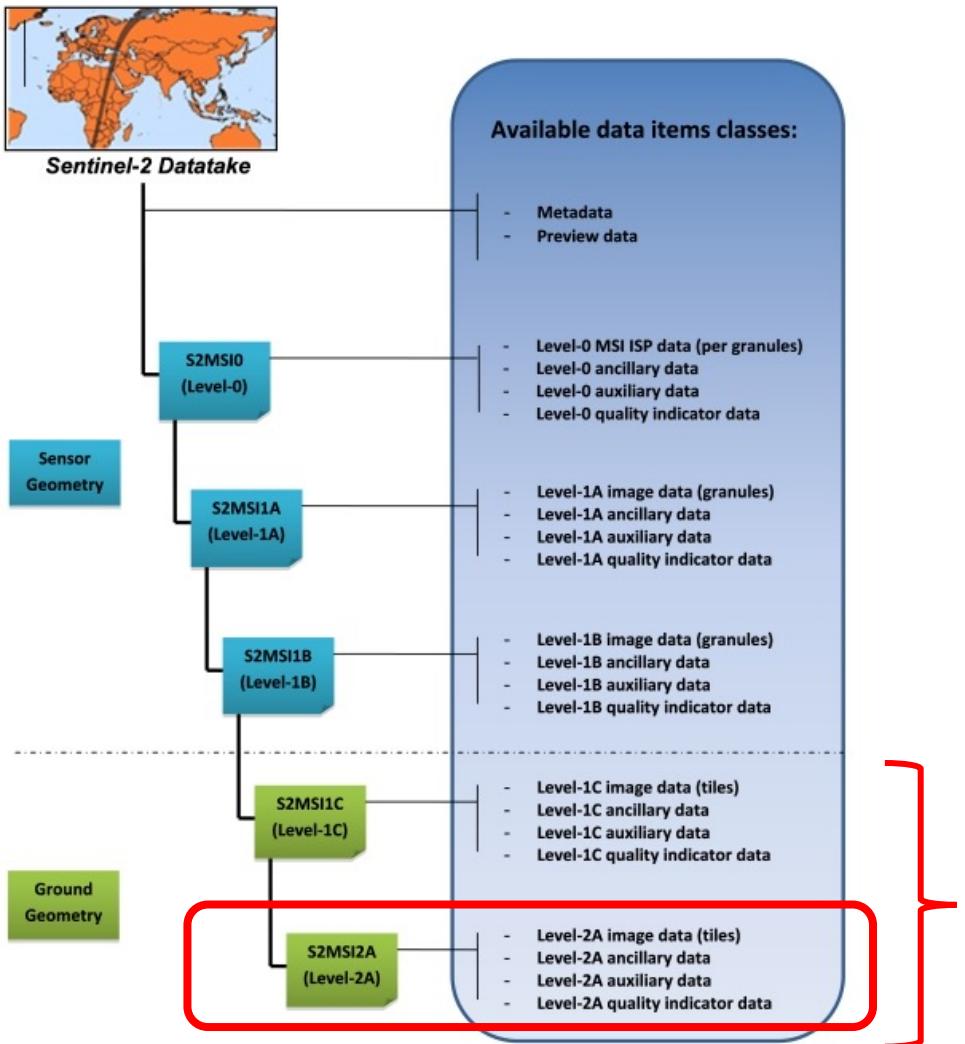
# Sentinel EO Browser

<https://www.sentinel-hub.com/explore/eobrowser/>

The screenshot displays the EO Browser interface with the following features:

- Header:** EO Browser logo, English language selection, and Login button.
- Top Bar:** Discover, Visualize, Compare, Pins, Go to Place search bar, and various icons for data layers, 3D view, and help.
- Dataset Selection:** Dataset: Sentinel-2 L2A, Date: 2018-07-27, Timespan, and a dropdown menu for "Show L1C".
- Legend:** A sidebar listing eight visualizations:
  - True color (Based on bands 4,3,2)
  - False color (Based on bands 8,4,3)
  - NDVI (Based on combination of bands (B8 - B4)/(B8 + B4))
  - False color (urban) (Based on bands 12,11,4)
  - Moisture index (Based on combination of bands (B8A - B11)/(B8A + B11))
  - SWIR (Based on bands 12,8A,4)
  - NDWI (Based on combination of bands (B3 - B8)/(B3 + B8))
- Map:** A satellite map of the Louvain-la-Neuve area, Belgium, showing urban centers like Louvain-la-Neuve, BLOCRY, and BRUYÈRES, along with surrounding agricultural fields. Labels for "éde de Namur", "Fourmillière", "LAUZELLE", "LA BARAQUE", "L'HOCAILLE", "BIÉREAU", and "VIEUX BRUYÈRES" are visible.
- Bottom Bar:** Free sign up for all features, Powered by Sentinel Hub with contributions by ESA v3.0.83, and links to About EO Browser, Contact us, and Get data.
- Coordinates:** Lat: 50.68721, Lng: 4.54388, and a 500 m scale bar.

# Sentinel-2 – Processing Levels



The image is divided into 100 km tiles in UTM/WGS84 projection.

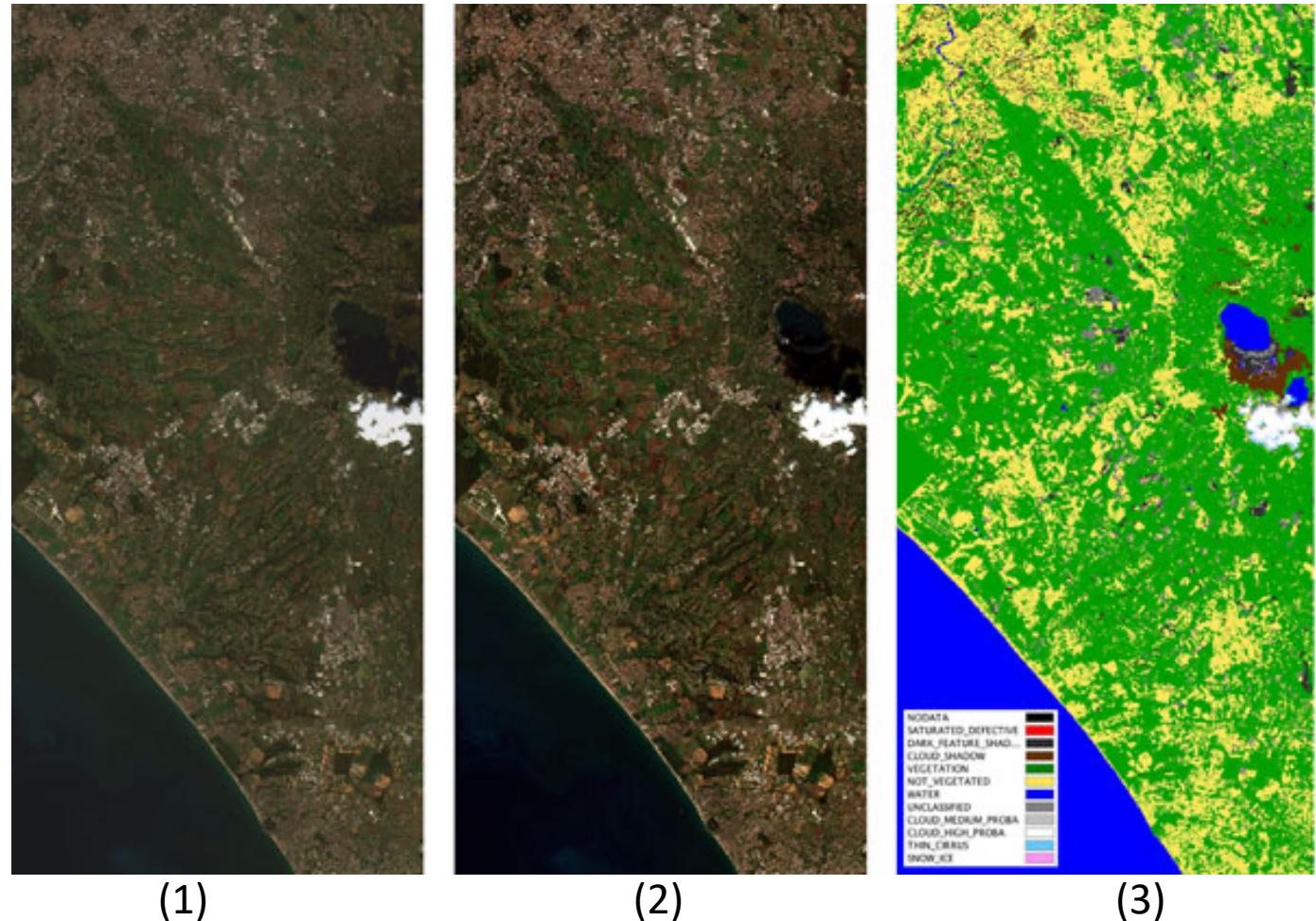
# Sentinel-2 – Level-2A

Level 2A-processing is split into two parts:

- **Scene Classification (SC)** aims at providing a pixel classification map
- **Atmospheric Correction (S2AC)** aims at transforming TOA reflectance into BOA reflectance.

Label	Classification
0	NO_DATA
1	SATURATED_OR_DEFECTIVE
2	DARK_AREA_PIXELS
3	CLOUD_SHADOWS
4	VEGETATION
5	NOT_VEGETATED
6	WATER
7	UNCLASSIFIED
8	CLOUD_MEDIUM_PROBABILITY
9	CLOUD_HIGH_PROBABILITY
10	THIN_CIRRUS
11	SNOW

Scene Classification Value



(1) Sentinel-2 Level-1C TOA reflectance input image,  
(2) the atmospherically corrected Level-2A BOA reflectance image,  
(3) the output scene classification of the Level-1C product

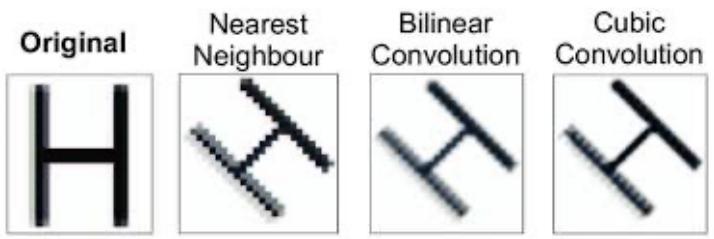
Extract ROI from  
satellite image



# Draw a perfectly rectangular ROI



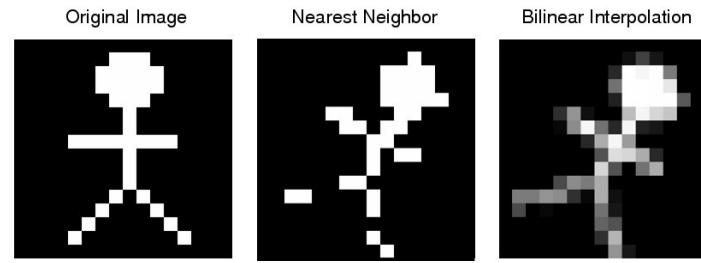
Coordinates Reference System (CRS)	
Geographic CRS	Projected CRS
degrees	meters
Lat/Lon	X/Y
World Geodetic System 1984 (WGS 84)	Universal Transverse Mercator (UTM)
EPSG:4326	EPSG:32631



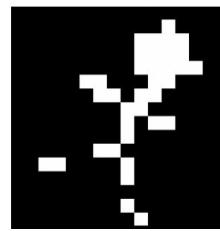
Bilinear Convolution



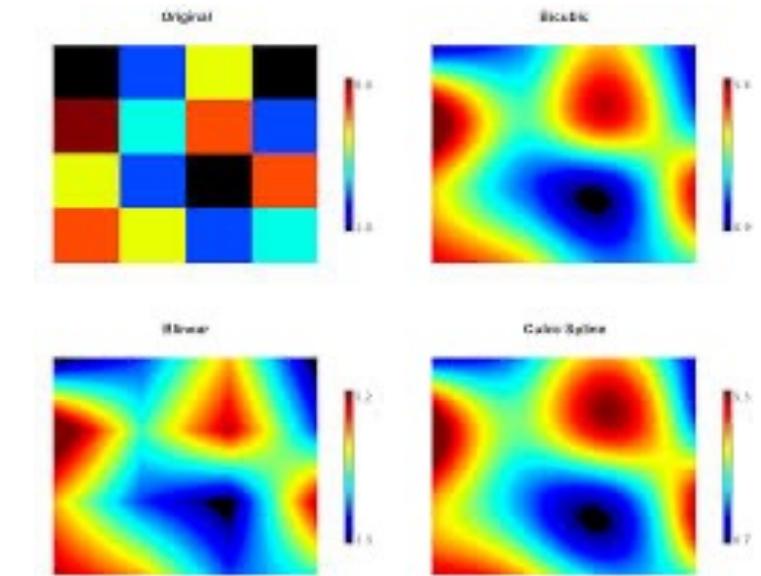
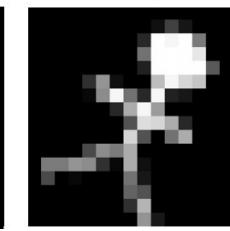
Cubic Convolution



Nearest Neighbor



Bilinear Interpolation

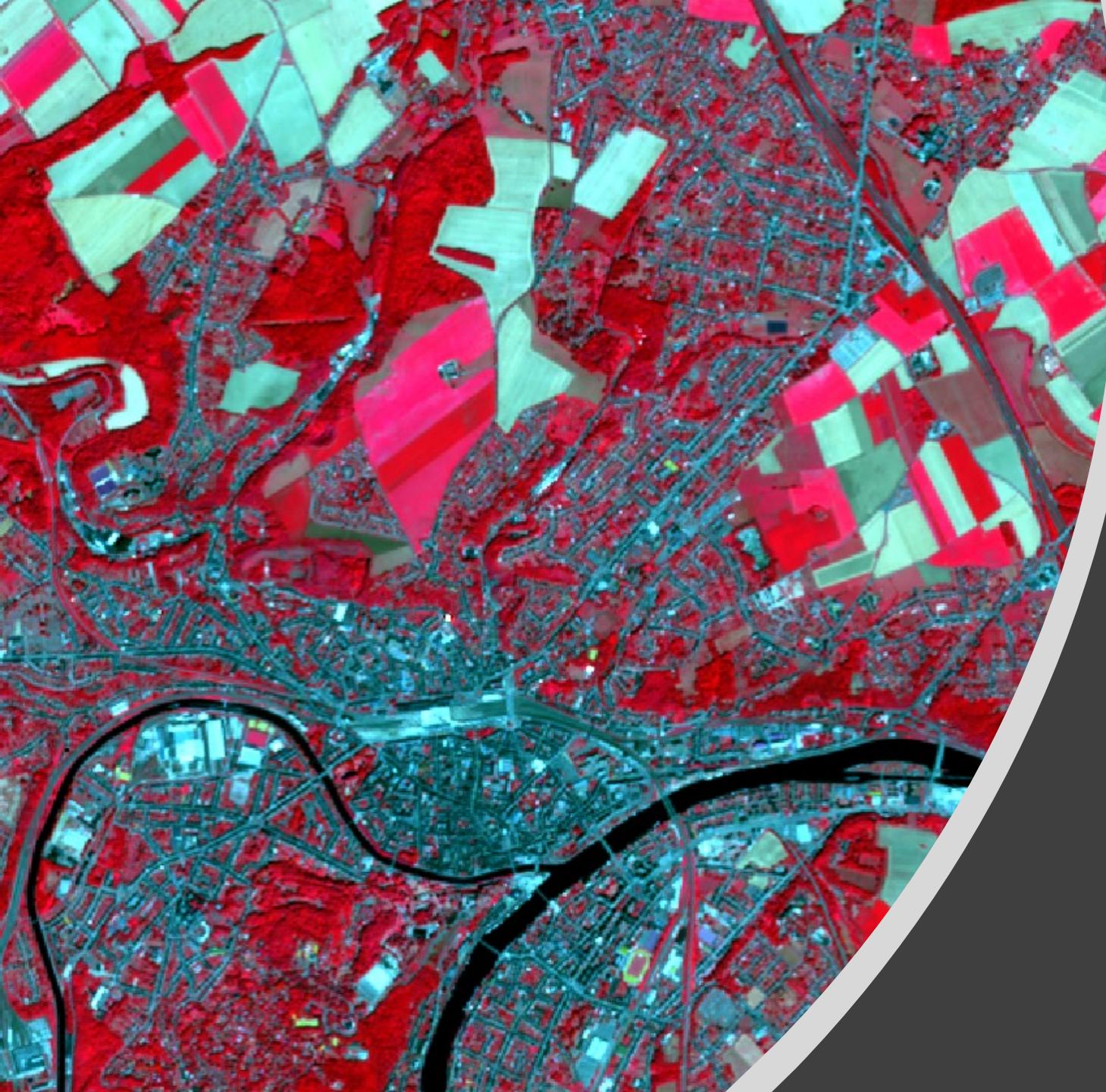


# Resampling

# Resampling methods

*Determine how the cell values of an output raster are determined after a geometric operation is done*

<b>Nearest Neighbor</b>	<ul style="list-style-type: none"><li>- Best used for <a href="#">categorical data</a> like land-use classification or slope classification.</li><li>- The value of the output cell is determined by the nearest cell center on the input grid</li></ul>
<b>Bilinear Interpolation</b>	<ul style="list-style-type: none"><li>- Weighted average of the four nearest cell centers. The closer an input cell center is to the output cell center, the higher the influence of its value is on the output cell value.</li><li>- The output value could be different than the nearest input but is always within the same range of values as the input.</li><li>- Since the values can change, Bilinear is not recommended for categorical data. Instead, it should be used for <a href="#">continuous data</a> like elevation and raw slope values.</li></ul>
<b>Cubic Convolution</b>	<ul style="list-style-type: none"><li>- Looks at the 16 nearest cell centers to the output and fits a smooth curve through the points to find the value.</li><li>- Not only does this change the values of the input but it could also cause the output value to be outside of the range of input values (imagine a sink or a peak occurring on a surface).</li><li>- This method is also not recommended for categorical data but does an excellent job of smoothing <a href="#">continuous data</a></li></ul>

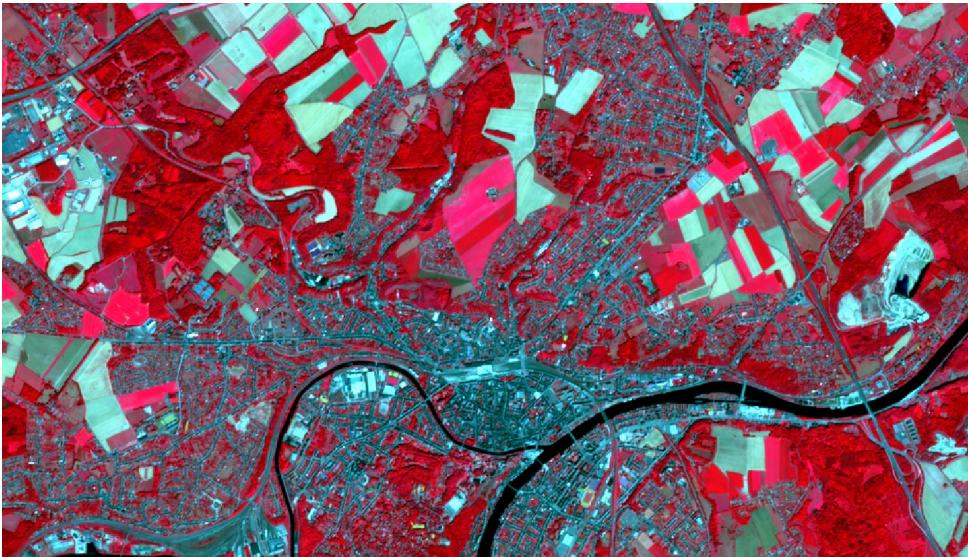


Create  
composite  
image

# Simple RGB Composites

## True Color

- Visible light bands : Red (B04), Green (B03) and Blue (B02) in the corresponding red, green and blue color channels
- Natural-colored result = good representation of the Earth as humans would see it naturally



## False Color

- Combination of standard near infra-red (B08), red (B04) and green (B03) band.
- To assess plant density and health, as plants reflect near infrared and green light, while absorbing red.
  - o Since they reflect more near infrared than green, plant-covered land appears deep red. Denser plant growth is darker red.
  - o Cities and exposed ground are gray or tan, and water appears blue or black.

# Biophysical Indicators

## ***Normalized Difference Vegetation Index***

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

## ***Normalized Difference Water Index***

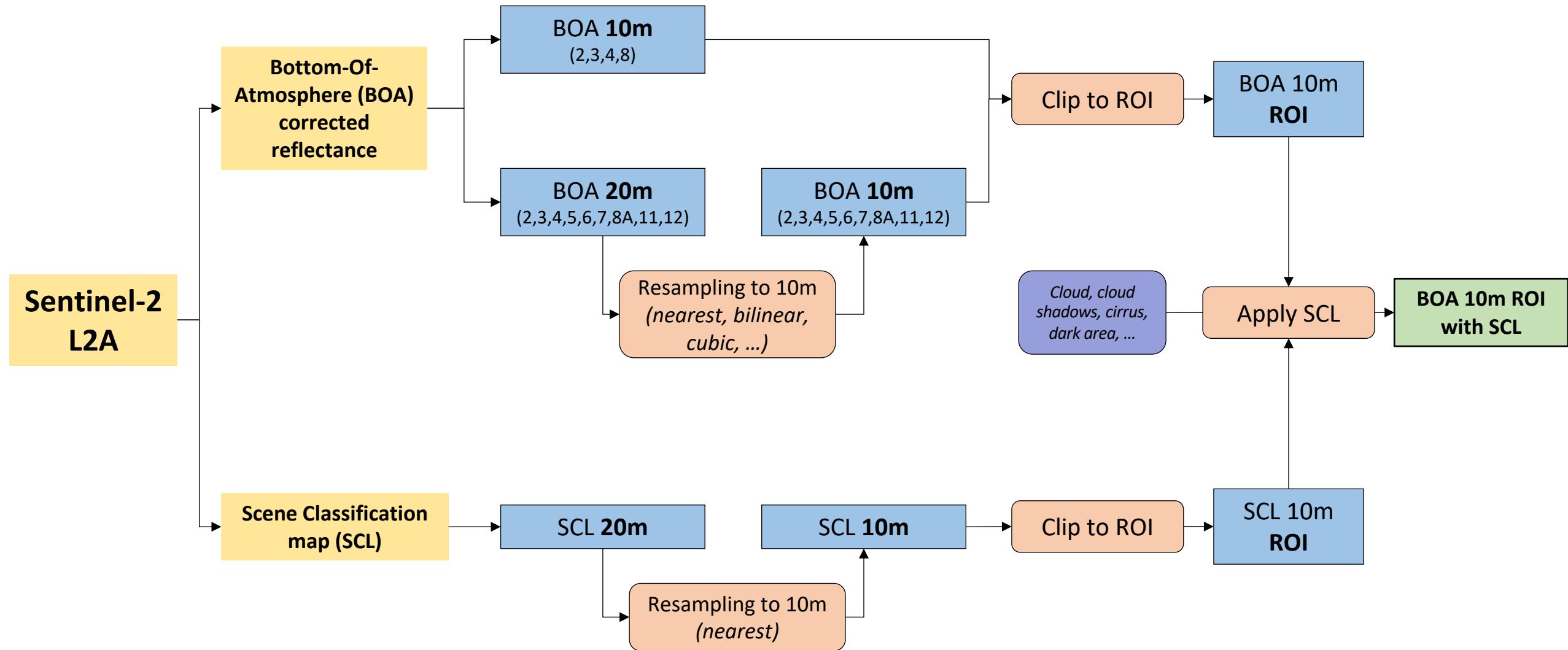
$$NDWI = \frac{GREEN - NIR}{GREEN + NIR}$$

## ***Brightness Index***

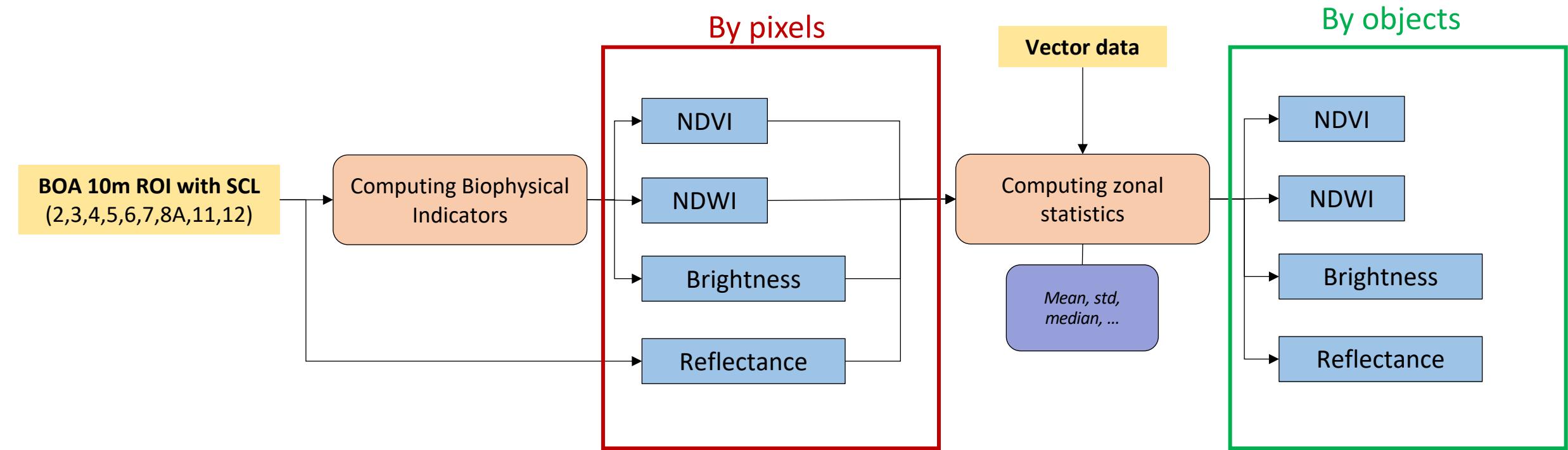
$$\text{Brightness} = \sqrt{GREEN^2 + RED^2 + NIR^2 + SWIR^2}$$

*The use of NDWI and Brightness provided complementary information improving the discrimination between crop and no-crop areas.*

# Pre-processing Sentinel-2 images



# Working by pixels or by objects



# Change detection

EO-derived data at time T-n  
(reflectance, NDVI, NDWI, ...)

EO-derived data at time T-1  
(reflectance, NDVI, NDWI, ...)

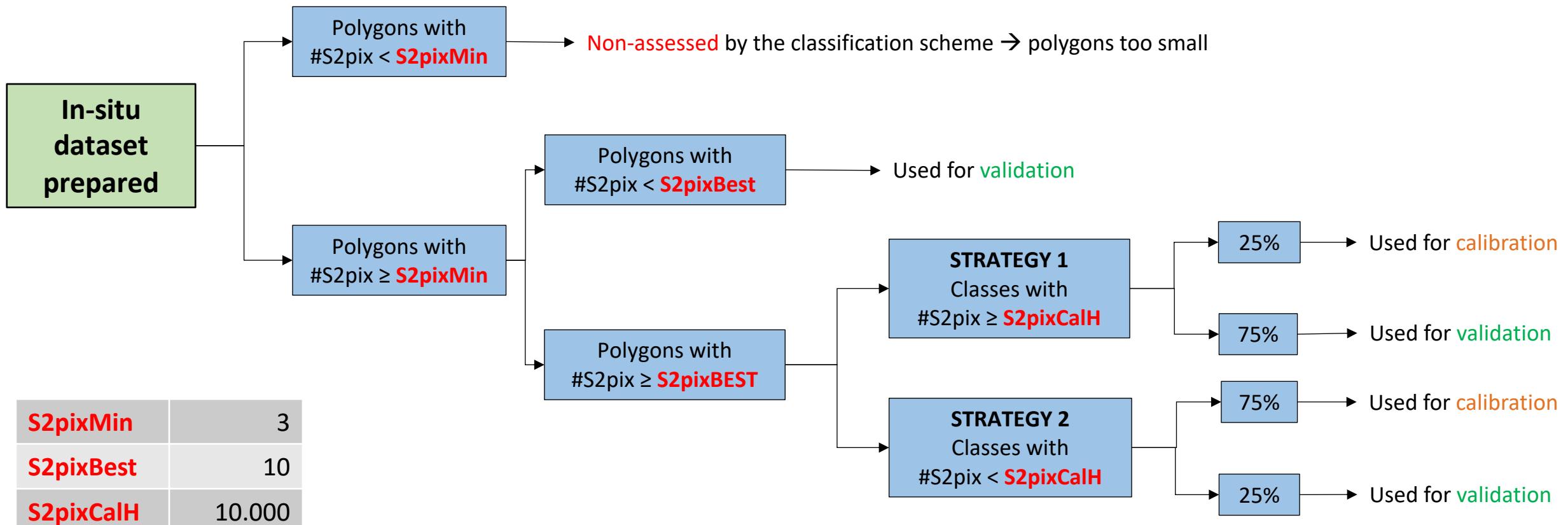
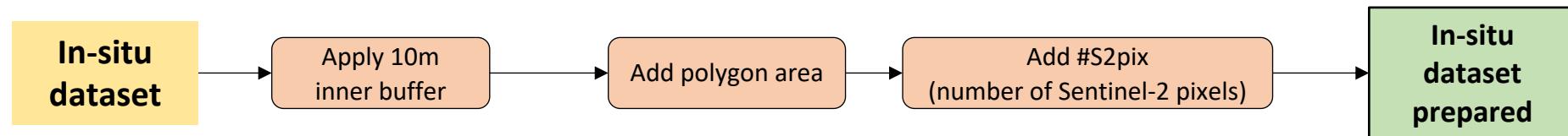
EO-derived data at time T  
(reflectance, NDVI, NDWI, ...)

1. Open rasters with *rasterio* into array
2. Using *numpy* you can do all kinds of matrix calculations
3. Create a new matrix with the change values you want to observe
4. Save this matrix into a new GeoTIFF to display in QGIS

Exemple:

- calculate the difference between the NDVI values at time T-1 and time T
- if the difference is greater than a certain value then there is urbanization
- !! A low NDVI value corresponds to Urban but also to bare soil and water !!

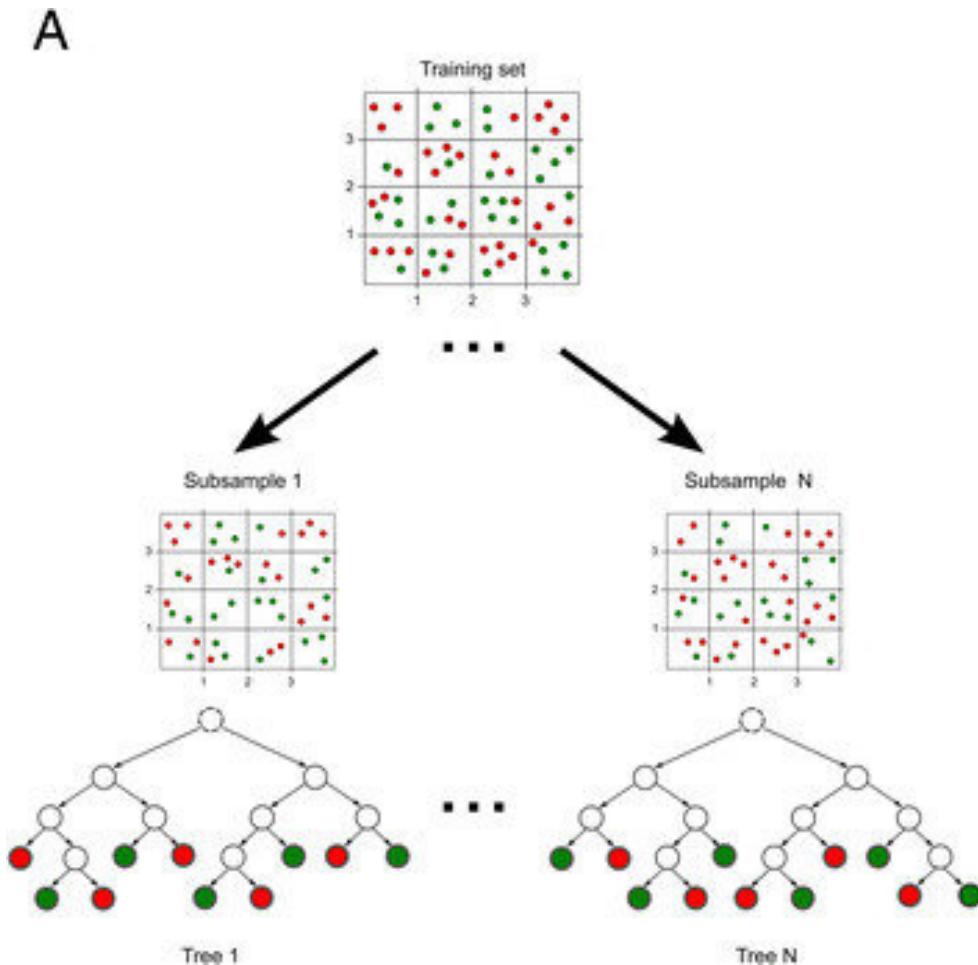
# In-situ Sampling Design



# Random Forest Classification (1/2)

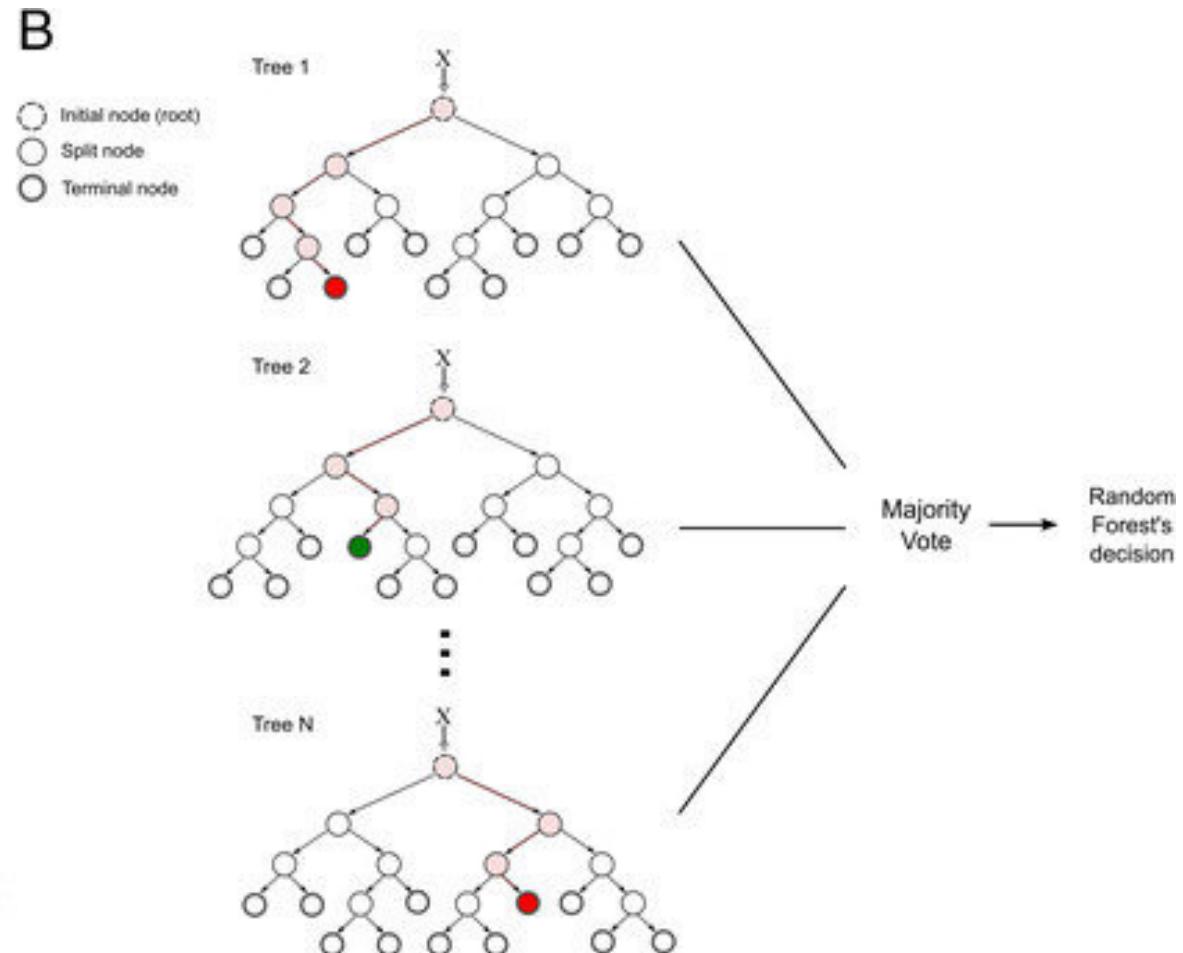
## A. Training

Each decision tree in the ensemble is built upon a random bootstrap sample of the original data, which contains positive (green labels) and negative (red labels) examples.

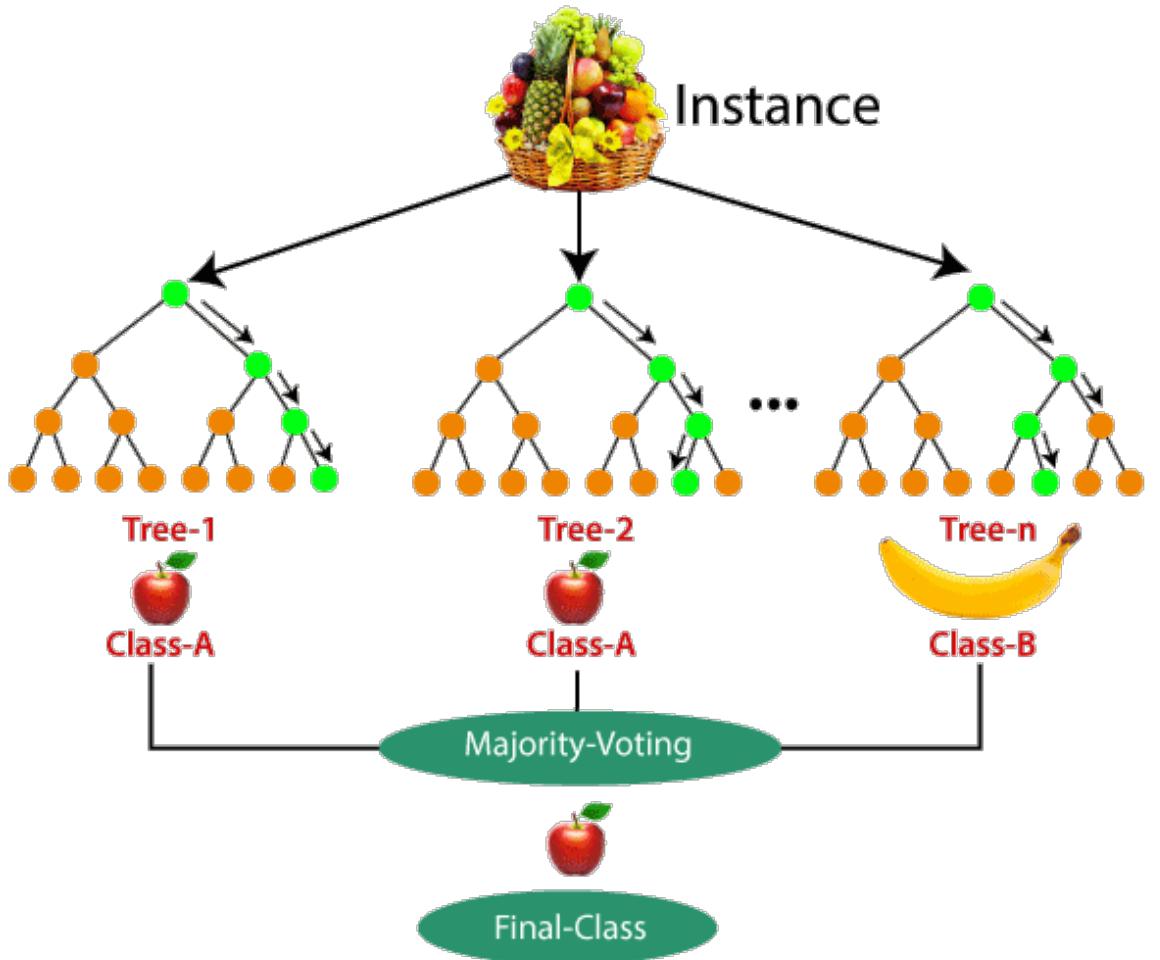


## B. Prediction

Class prediction for new instances using a random forest model is based on a majority voting procedure among all individual trees.



# Random Forest Classification (2/2)



The procedure carried out for each tree is as follows: for each new data point (i.e., X), the algorithm starts at the root node of a decision tree and traverse down the tree (green branches) testing the variables values in each of the visited split nodes (green nodes), according to each it selects the next branch to follow. This process is repeated until a leaf node is reached, which assigns a class to this instance.

At the end of the process, each tree casts a vote for the preferred class label. The random forest classifier collects the majority voting to provide the final prediction. The majority of the decision trees have chosen *apple* as their prediction. This makes the classifier choose *apple* as the final prediction.