University *of Ljubljana*
Faculty of *Civil and Geodetic Engineering*

esa

Forestry from Space

13th ESA Training Course on Earth Observation 2023

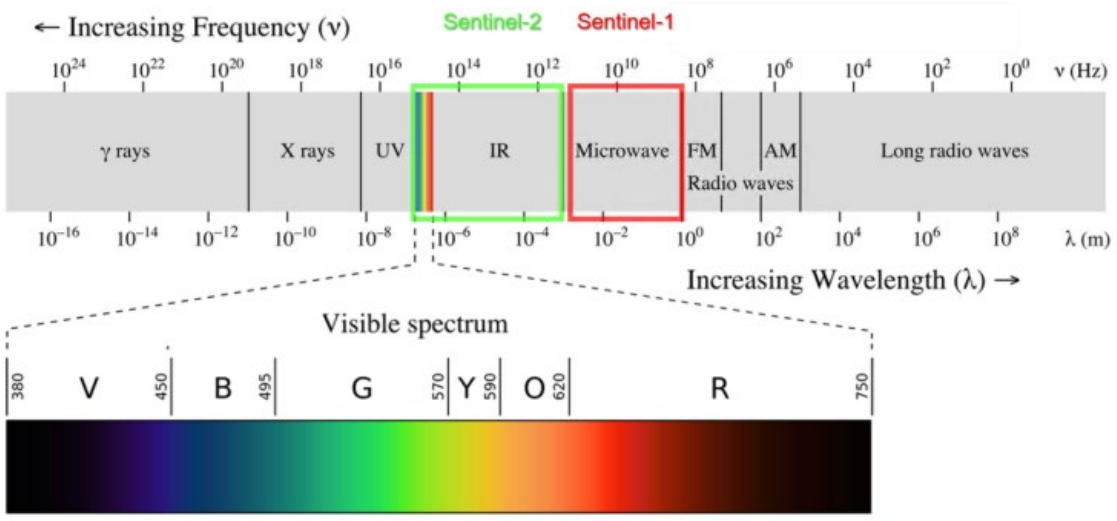
Using Sentinel-1 and Sentinel-2 for forestry

Asist. Ana Potočnik Buhvald

18 | 09 | 23 - 22 | 09 | 23

Osijek, Croatia

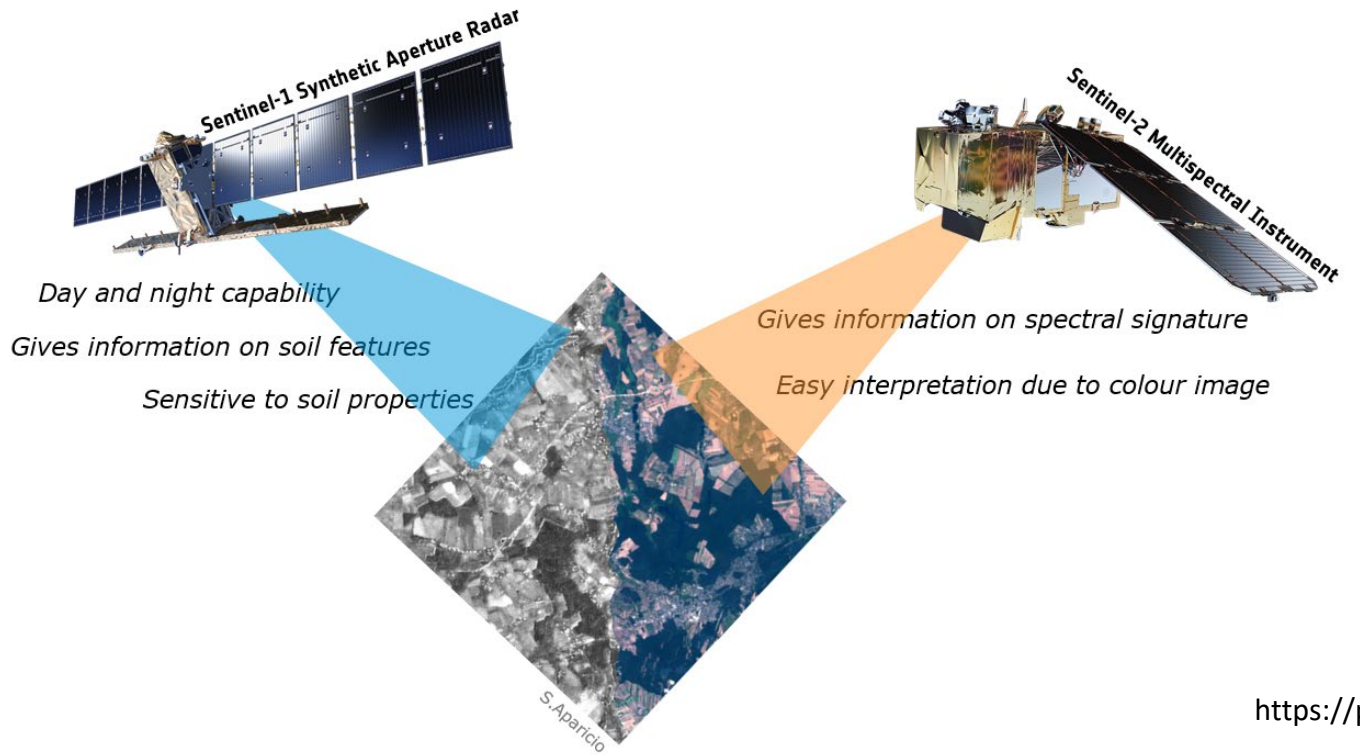
Combination of Sentinel-1 and Sentinel-2 images



Electromagnetic spectrum and S1 / S2 satellites (Ronan 2013, CC BY SA 3.0)

- combination of radar images from Sentinel-1 and multispectral images from Sentinel-2 to demonstrate their synergistic use and complementary information due to their different sensors and capabilities.

Sentinel-1 and Sentinel-2 fusion



https://philab.esa.int/big-data-fusion/

Fusion

There are fusion techniques that combine information from different sensors to exploit their complementary information content, usually at the pixel level (Ghassemian 2016, Pandit & Bhiwani 2015). Ideally, the images from both sensors are acquired at the same time. At the very least, the time between the two image products should be as short as possible to ensure that the information from each pixel relates to the same state of the Earth's surface.

How to combine data in SNAP:

Synergetic use of radar and optical data

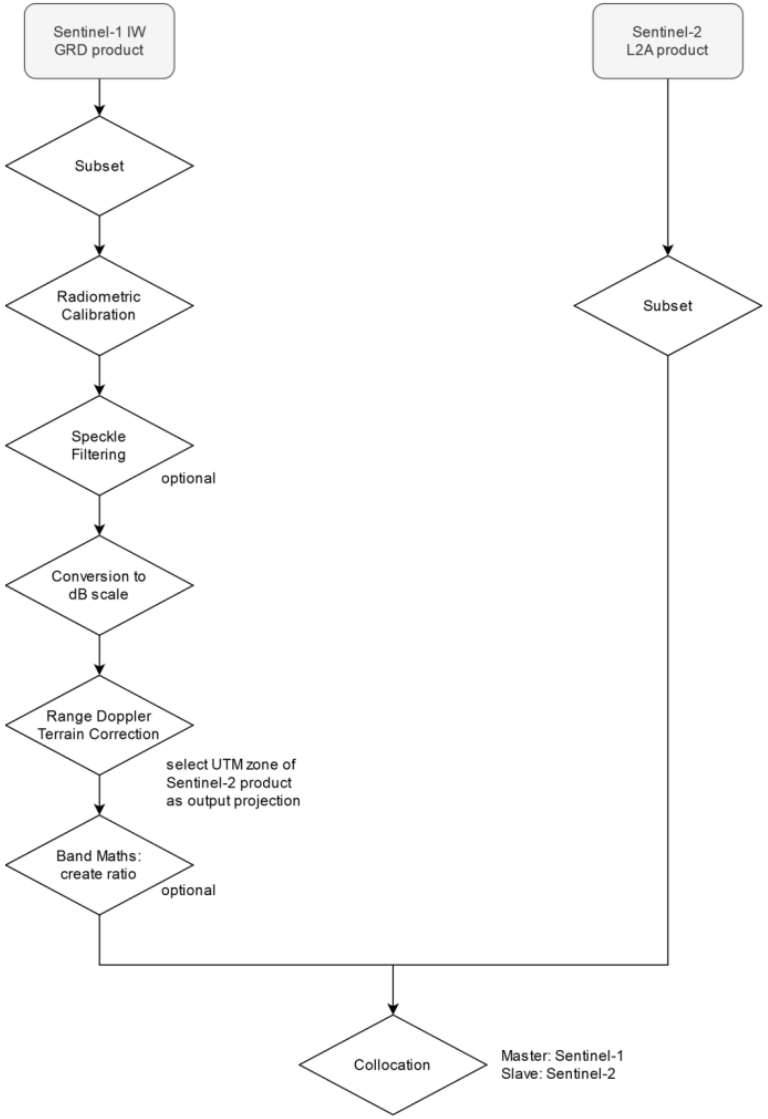
Download the Data from Copernicus Open Access Hub

- login required,
- registration is free.

In this tutorial we used:

SAR:
S1A_IW_GRDH_1SDV_20230902T051115_20230902T051140_050144_0608F8_4363

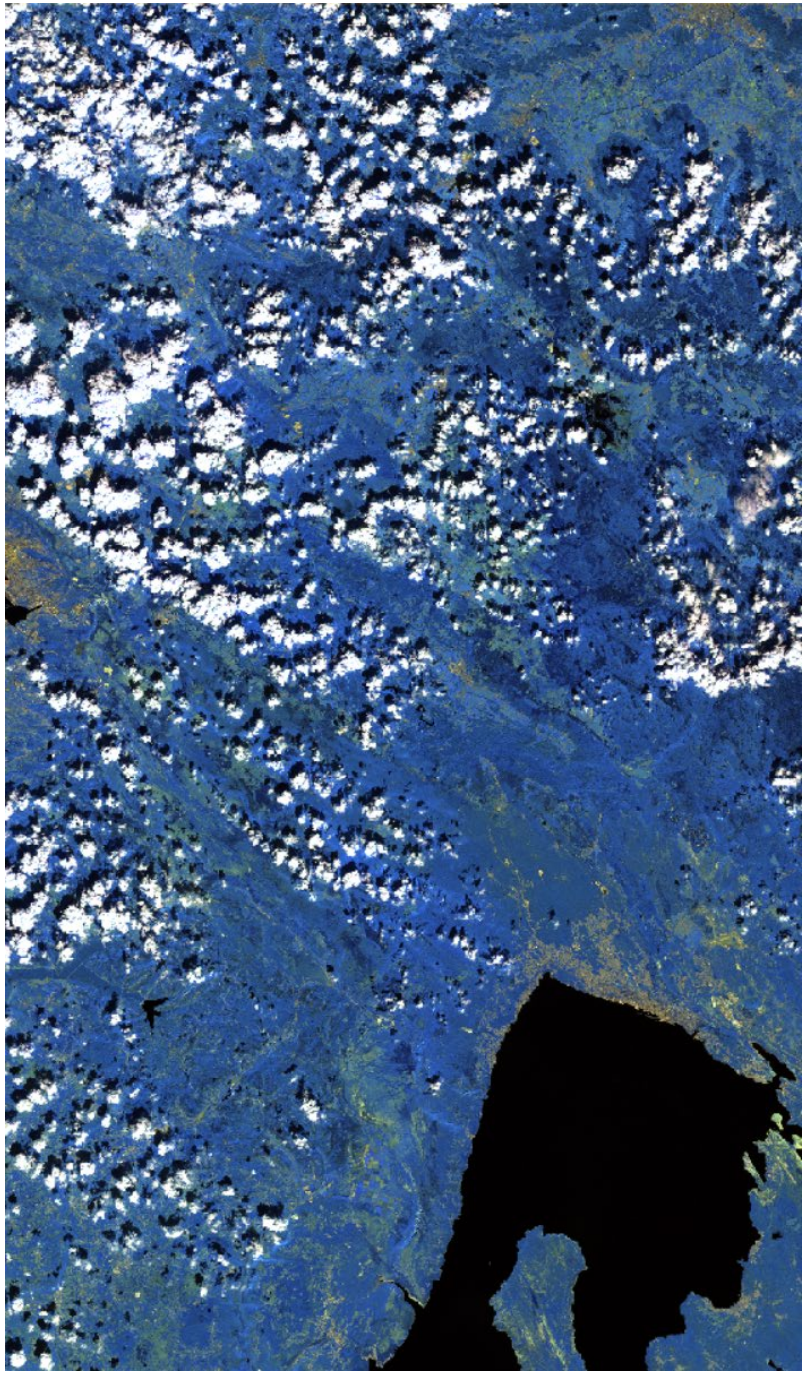
optical:
S2B_MSIL2A_20230902T095559_N0509_R122_T33TVL_20230902T131110



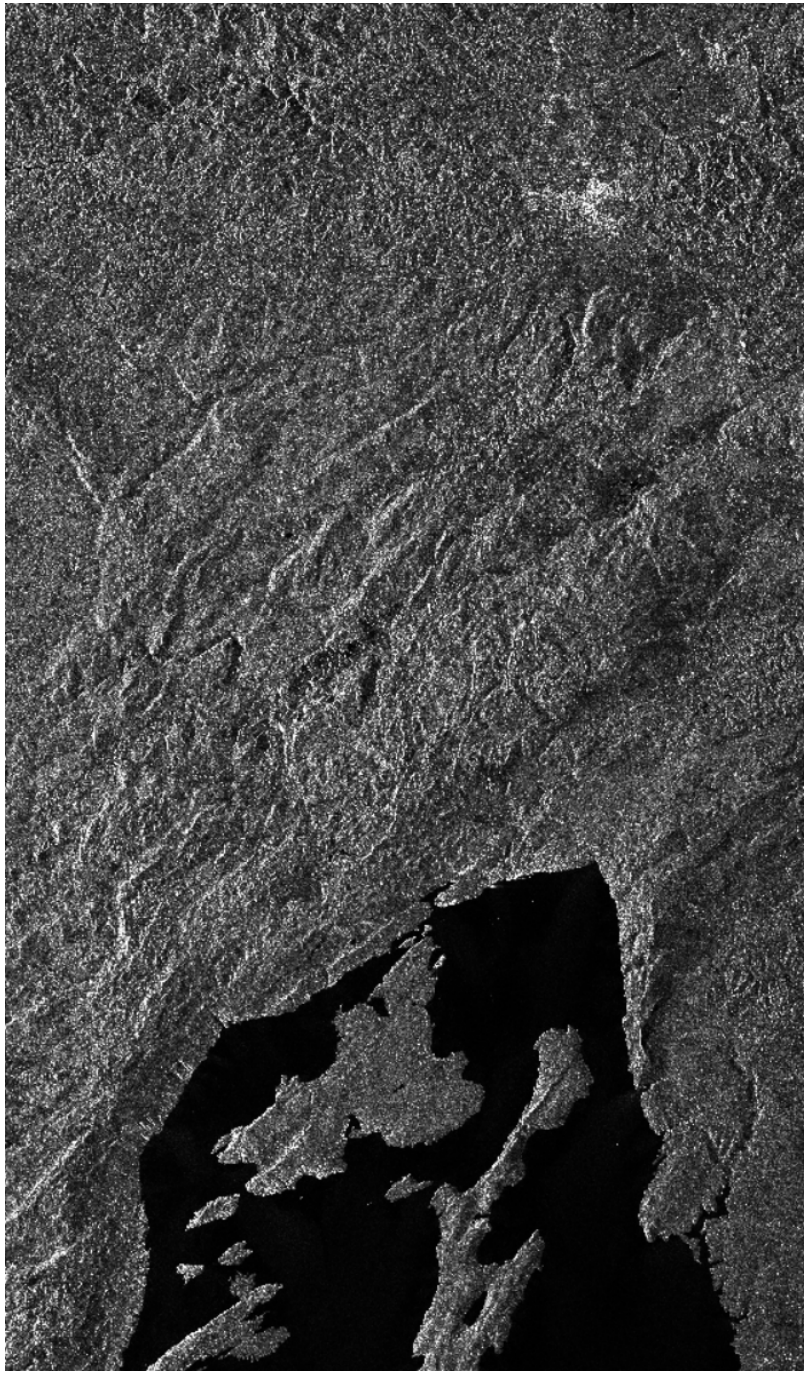
Workflow in SNAP

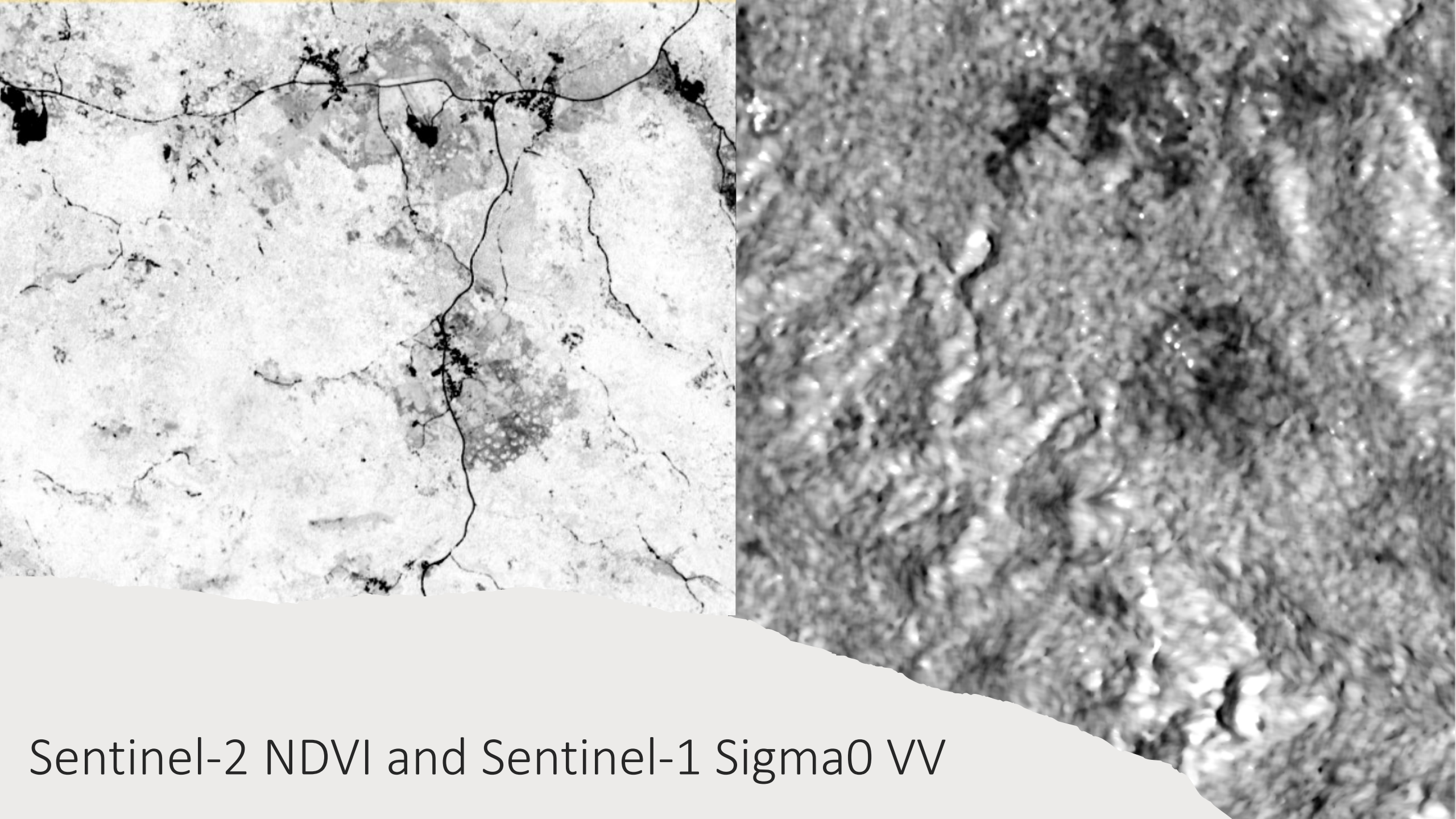
Area of interest


Austria
Hungary
Slovenia
Ljubljana
AOI
Croatia
Osijek
Italy
Serbia
Bosnia and
Herzegovina
https://www.kocevsko.com/en/kocevsko/virgin-forest-and-forests/




1
2
3



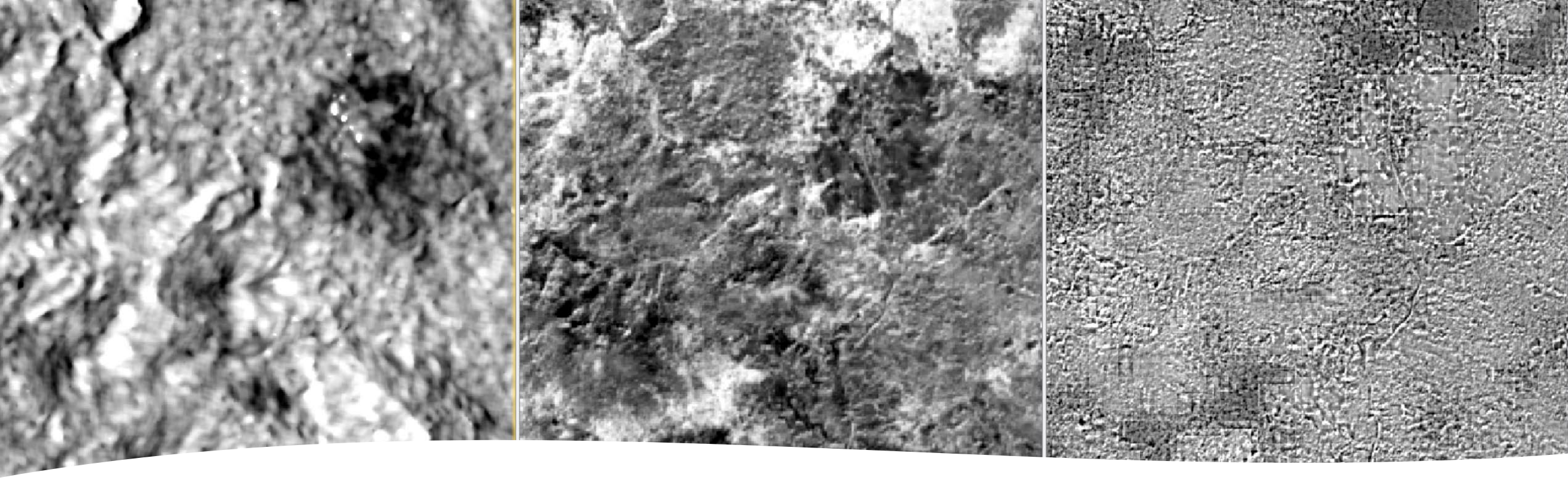


Sentinel-2 NDVI and Sentinel-1 Sigma0 VV

Suggestions for analyses of the merged product

Visual interpretation (R-G-B)

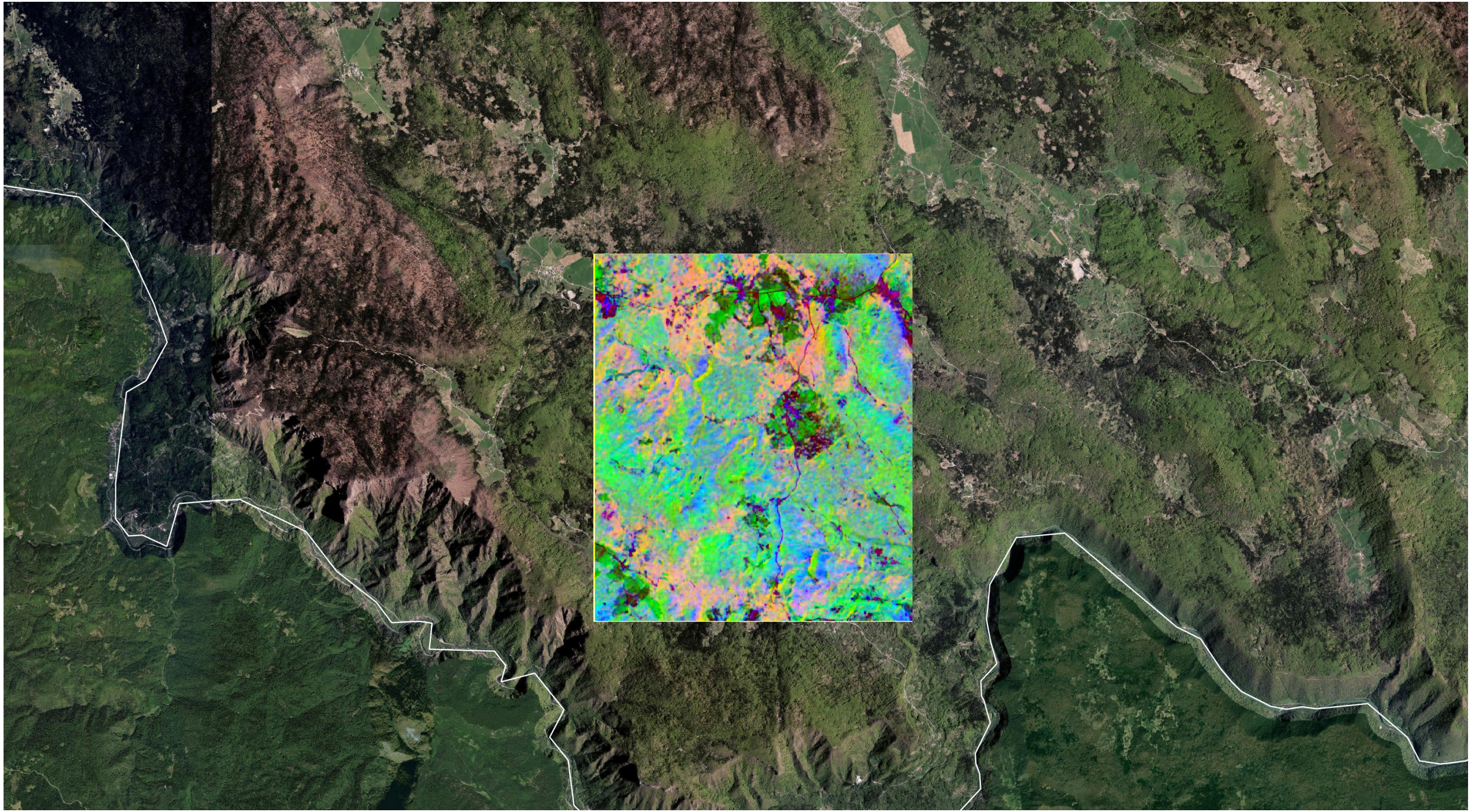
- red=S2-B4, green=S2-B3 and blue=S1-VV
- red=S2-B9, green=S2-B5, blue=S1-VH

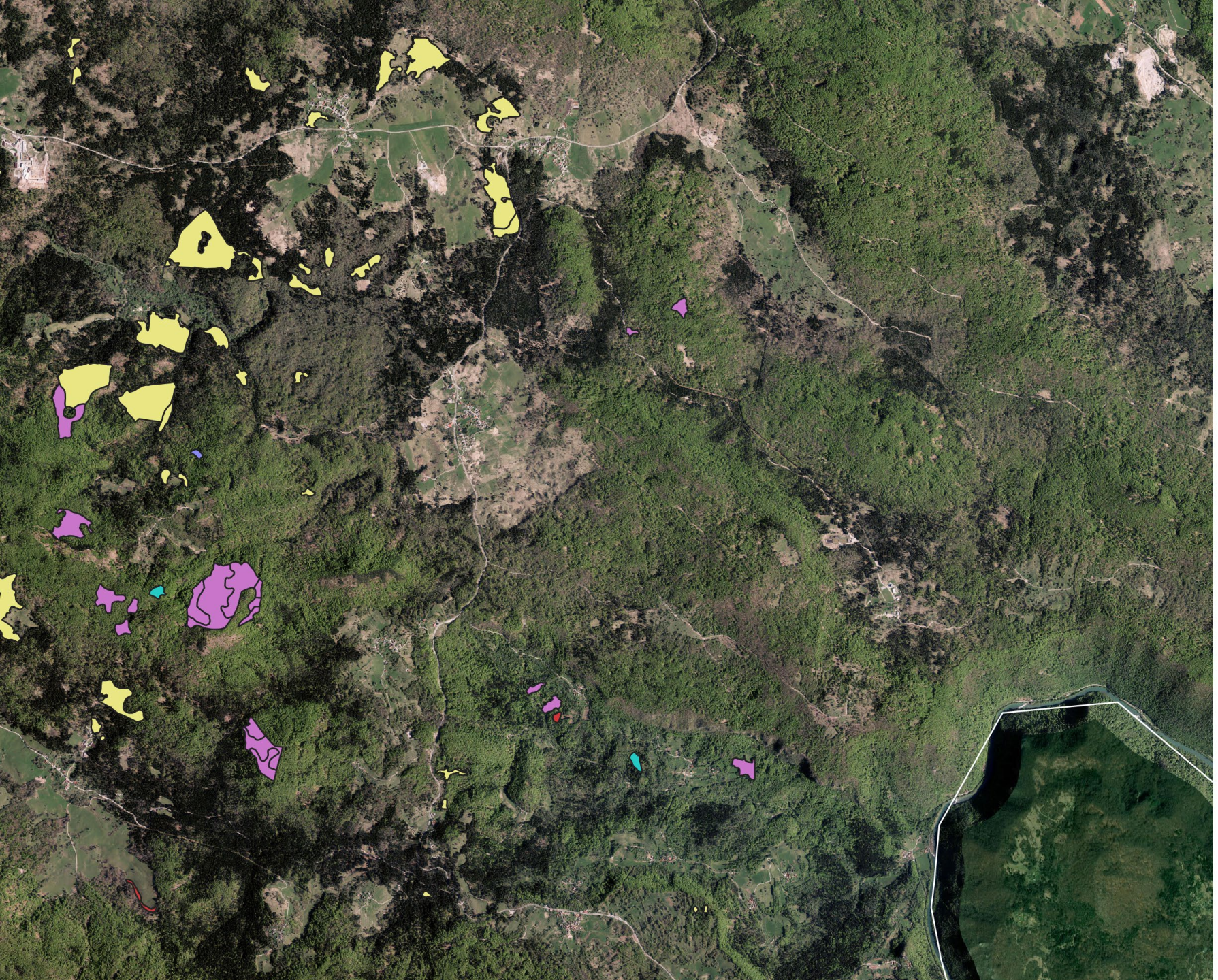


Principal component analysis

Create mask for AOI

- collocationFlags==1 is mask for PCA
- red=PC1, green=PC3, blue=PC5





Homogenous stands

- Alnus_glutinosa
- Fagus_sylvatica
- Picea_abies
- Pinus_sylvestris
- Quercus_petraea

Esri Satellite

broadleaf trees

Alnus glutinosa

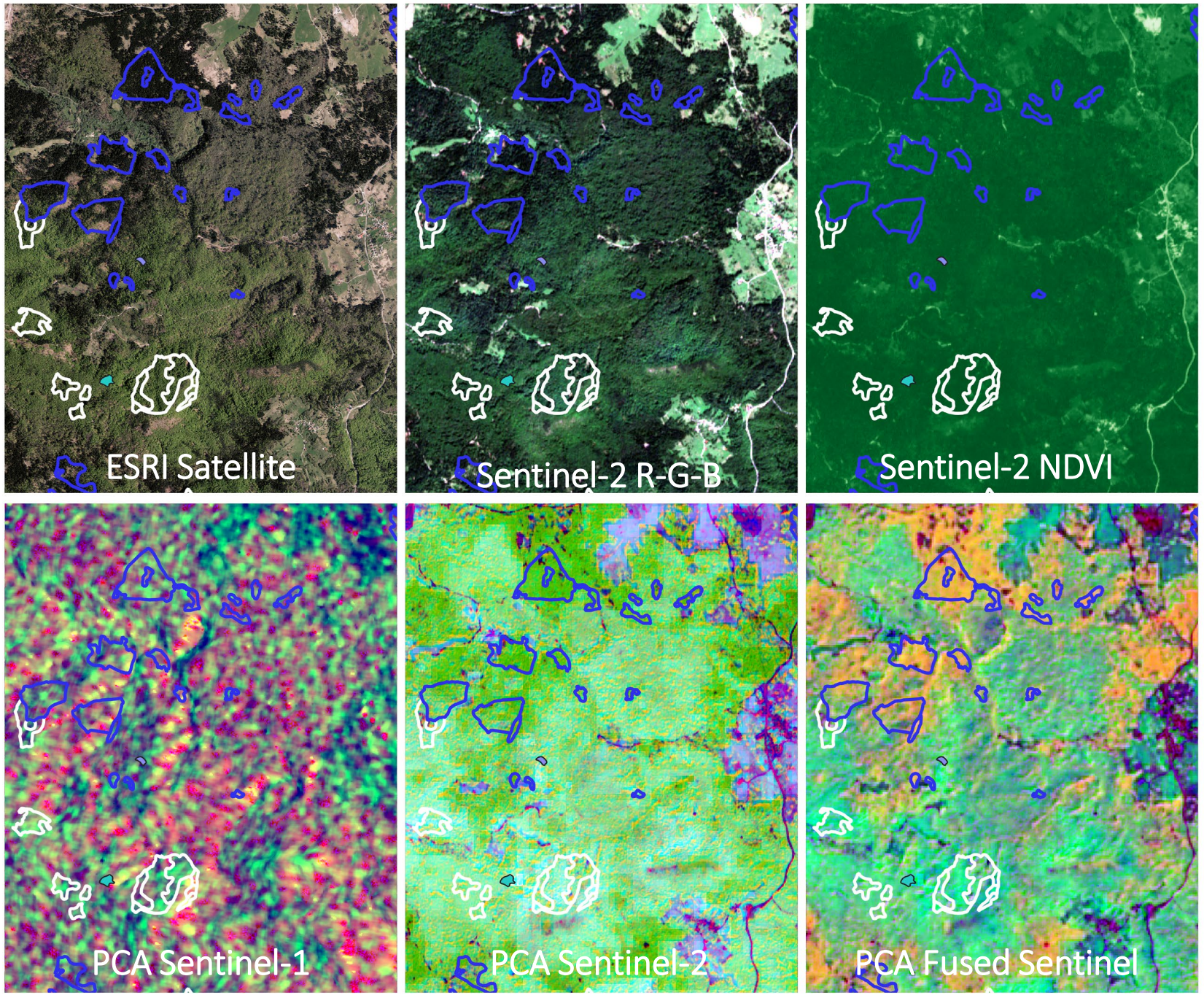
Fagus sylvatica

Quercus petraea

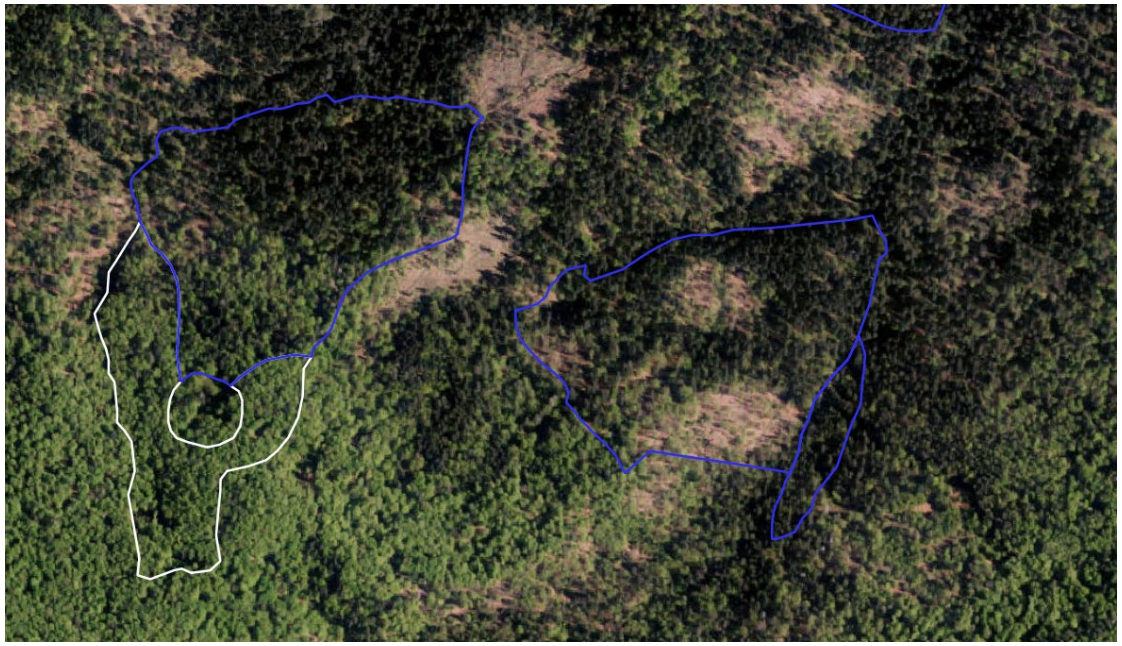
coniferous trees

Pinus sylvestris

Picea abies

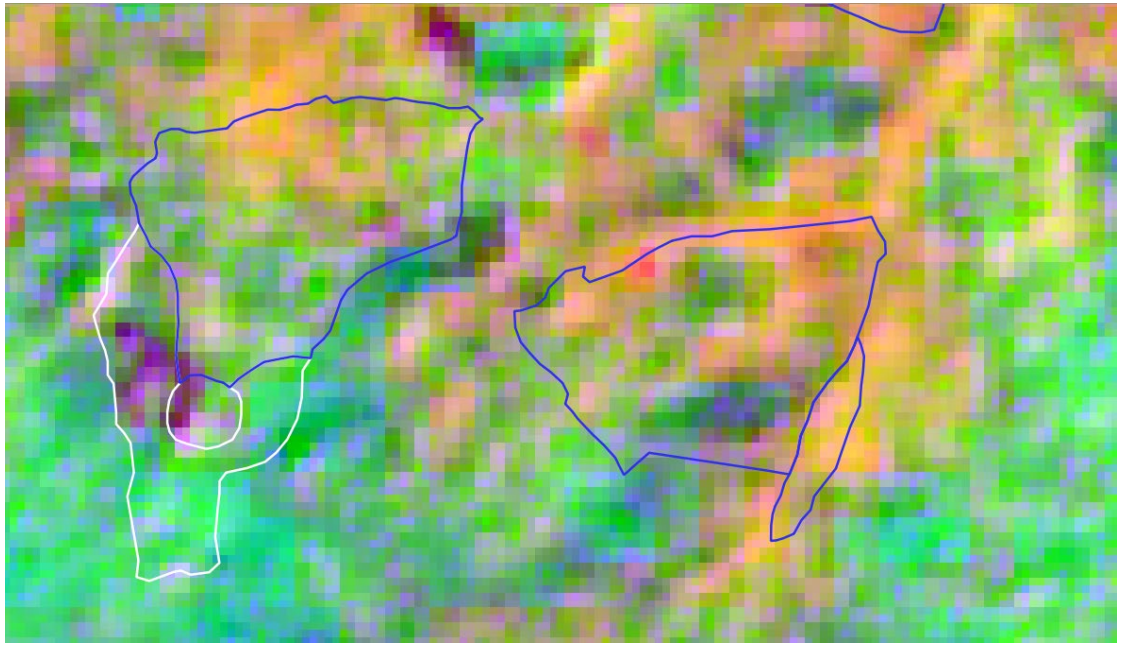

ESRI Satellite
Sentinel-2 R-G-B
Sentinel-2 NDVI
PCA Sentinel-1
PCA Sentinel-2
PCA Fused Sentinel

ESRI Satellite



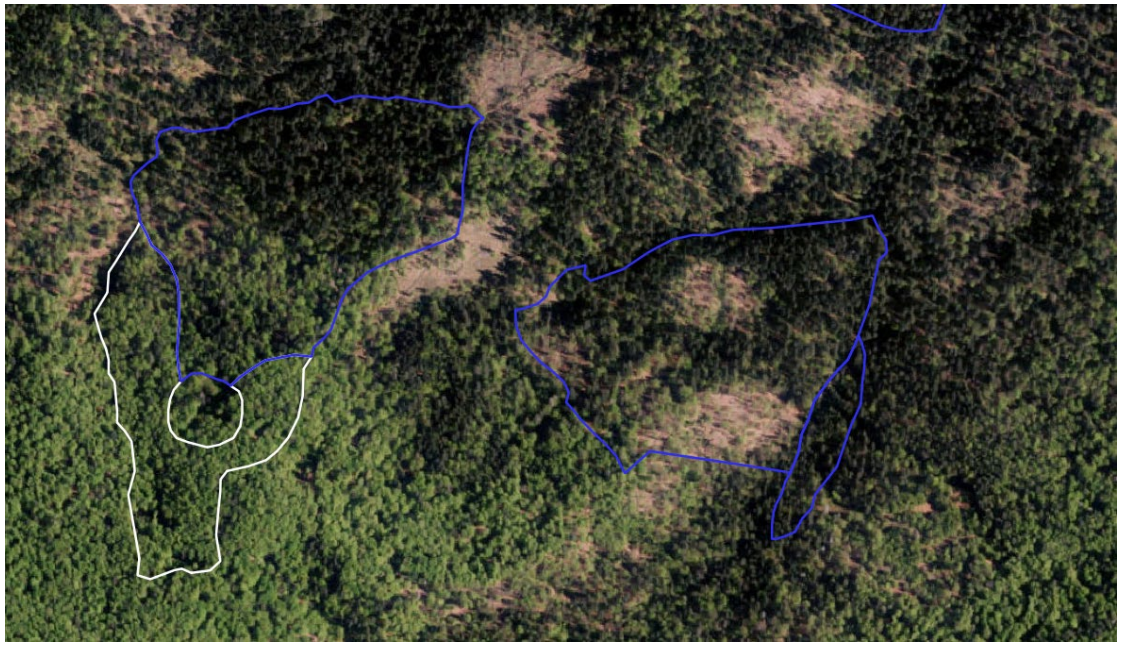
Deciduous trees tend to be green and blue in color, conifers tend to be orange in color.

PCA from combined Sentinel-1/-2 dataset

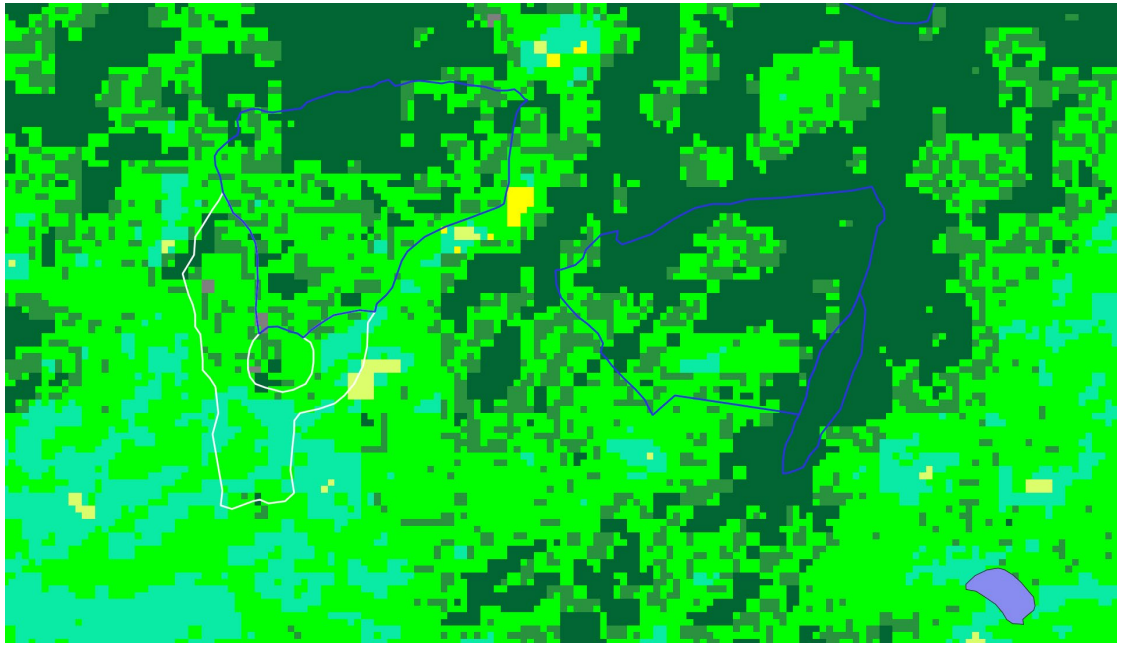


There is a difference between dense and rare forest area.

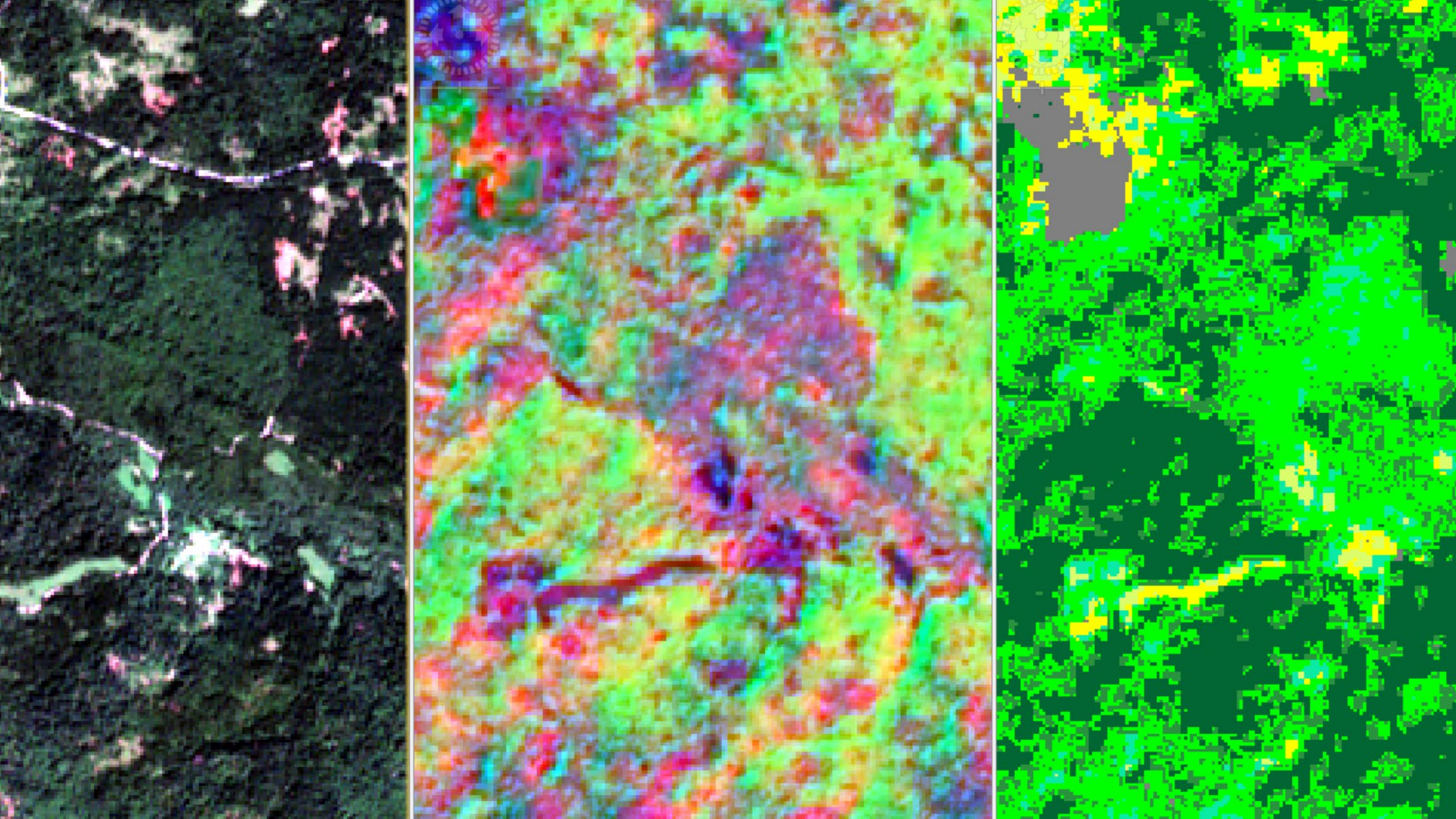
ESRI Satellite



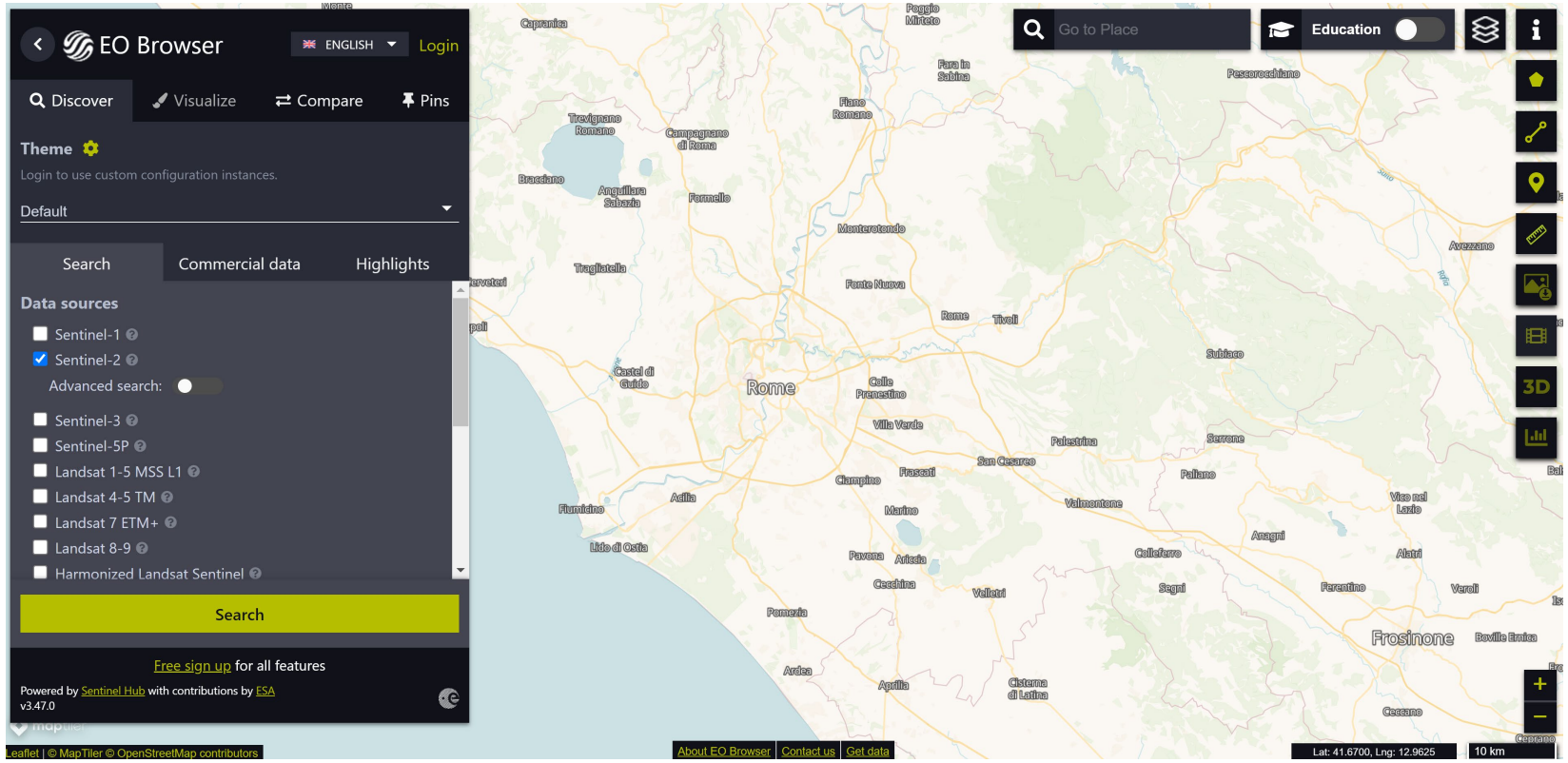
Unsupervised classification from Sentinel-2



There is a difference between broadleaf and coniferous forest.

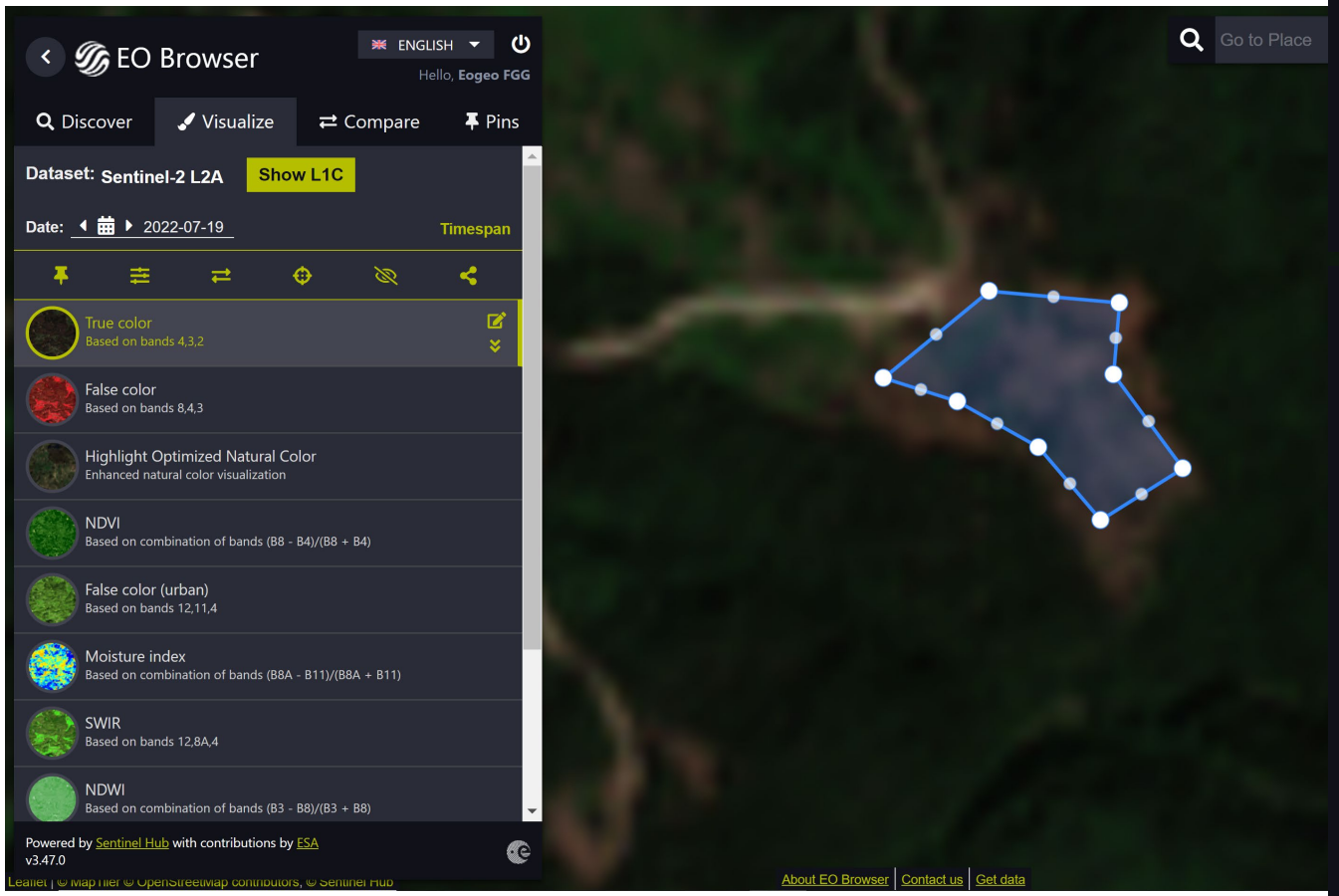


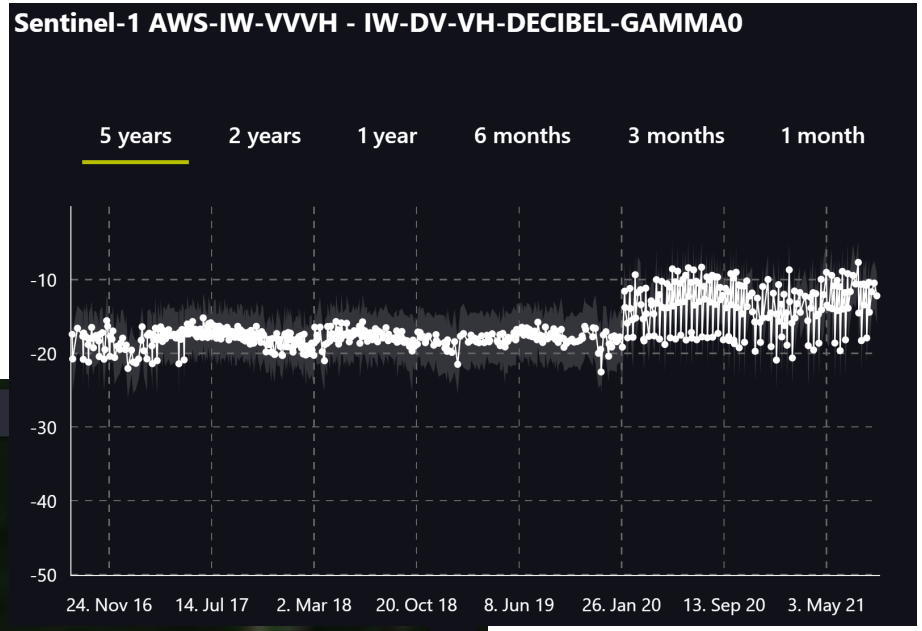
Sentinel Hub EO Browser

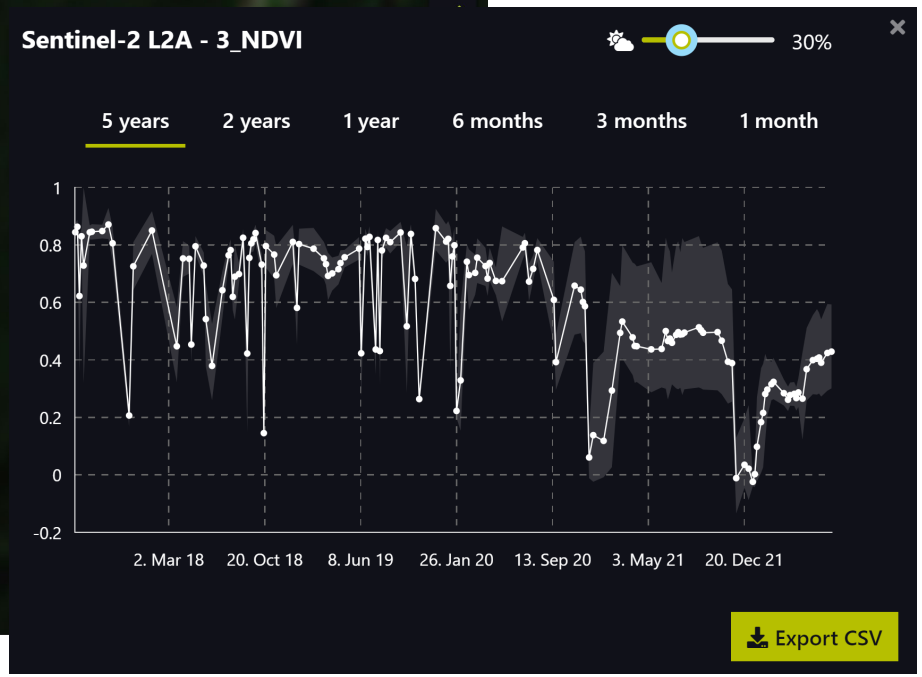


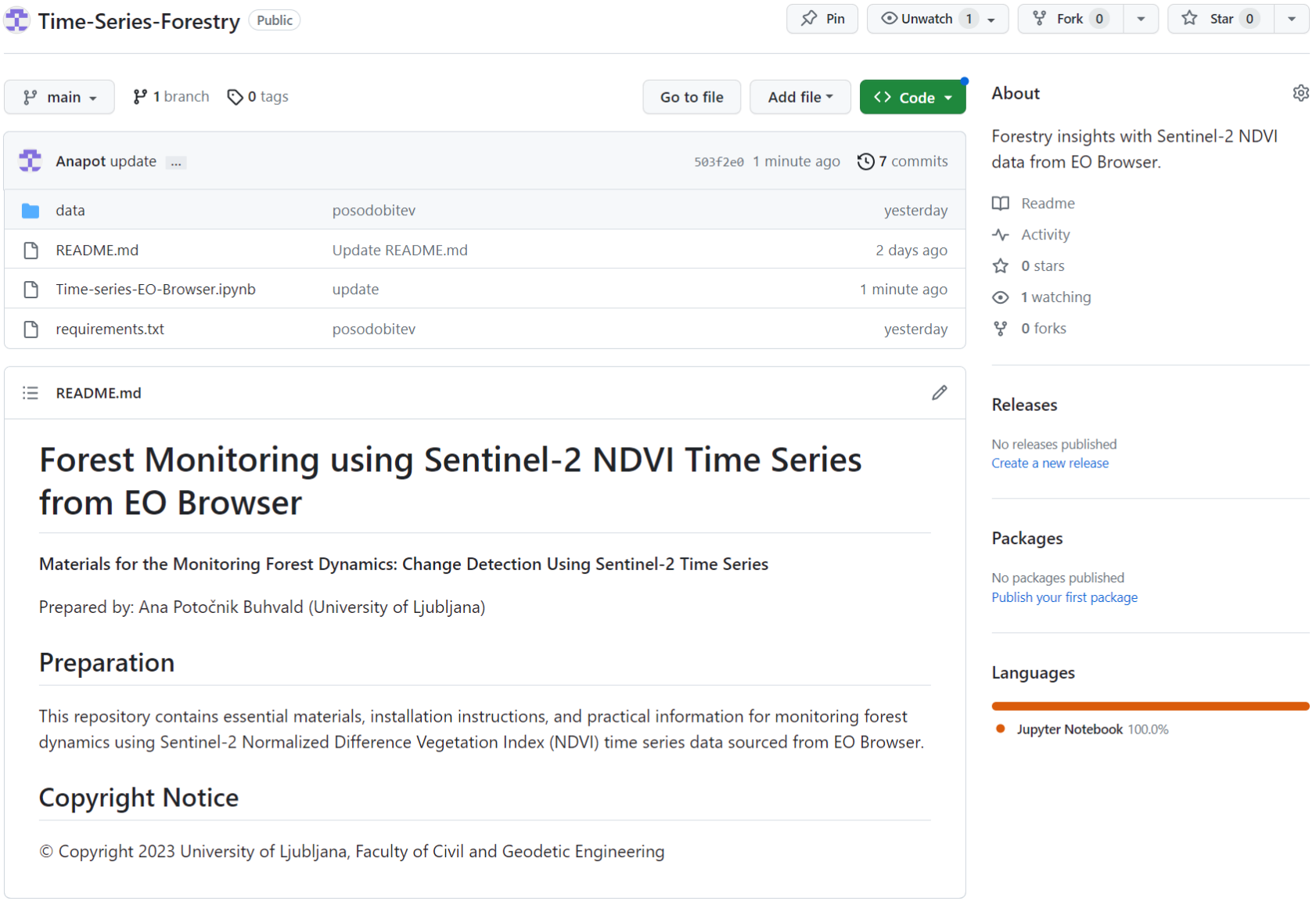
- more information how to use it at https://www.sentinel-hub.com/explore/eobrowser/
- https://www.youtube.com/playlist?list=PL46vEE2ks3tmYlhI7urPpiPw-WhLQHtSE (tutorials)

Time series analysis









Code available on: https://mybinder.org/v2/gh/Anapot/Time-Series-Forestry/HEAD?labpath=Time-series-EO-Browser.ipynb

Time Series from EO Browser

Description:

This Jupyter Notebook cell contains Python code that performs data analysis and visualization on a time series dataset of NDVI (Normalized Difference Vegetation Index) values from EO Browser. The code demonstrates the following steps:

1. **Loading and Analyzing NDVI Data from EO Browser:** The script loads a time series dataset from a CSV file using the Pandas library. It then converts the 'C0/date' column to datetime and sets it as the index for time-based analysis.
2. **Filter time series data:** The script select only cloud free values.
3. **Smoothing NDVI Data with Savitzky-Golay filter:** The script smooth time series with Savitzky-Golay filter.
4. **Resample time series data to identify trends and anomalies with annual values:** The NDVI signal is resampled to calculate yearly averages and standard deviations. This is achieved using the `resample` method, which aggregates the data or
5. **Change detection:** The yearly average NDVI values are separated into two groups based on a threshold value (0.55 in this case). The groups are 'Below Threshold' and 'Above or Equal Threshold.' This show in which year change happened.
6. **Visualizaton:** The script plot all getted values in same image or seperate look.

Usage:

You can use this code as a template for analyzing and visualizing time series data from EO Browser with Pandas and Matplotlib. It's particularly useful for assessing the annual trends in NDVI values and identifying periods above or below a specified th

Note:

Make sure to have the 'time_series_file.csv' file in the same directory as this notebook before running the code.

Author: (c) Ana Potočnik Buhvald, UL FGG, 2023

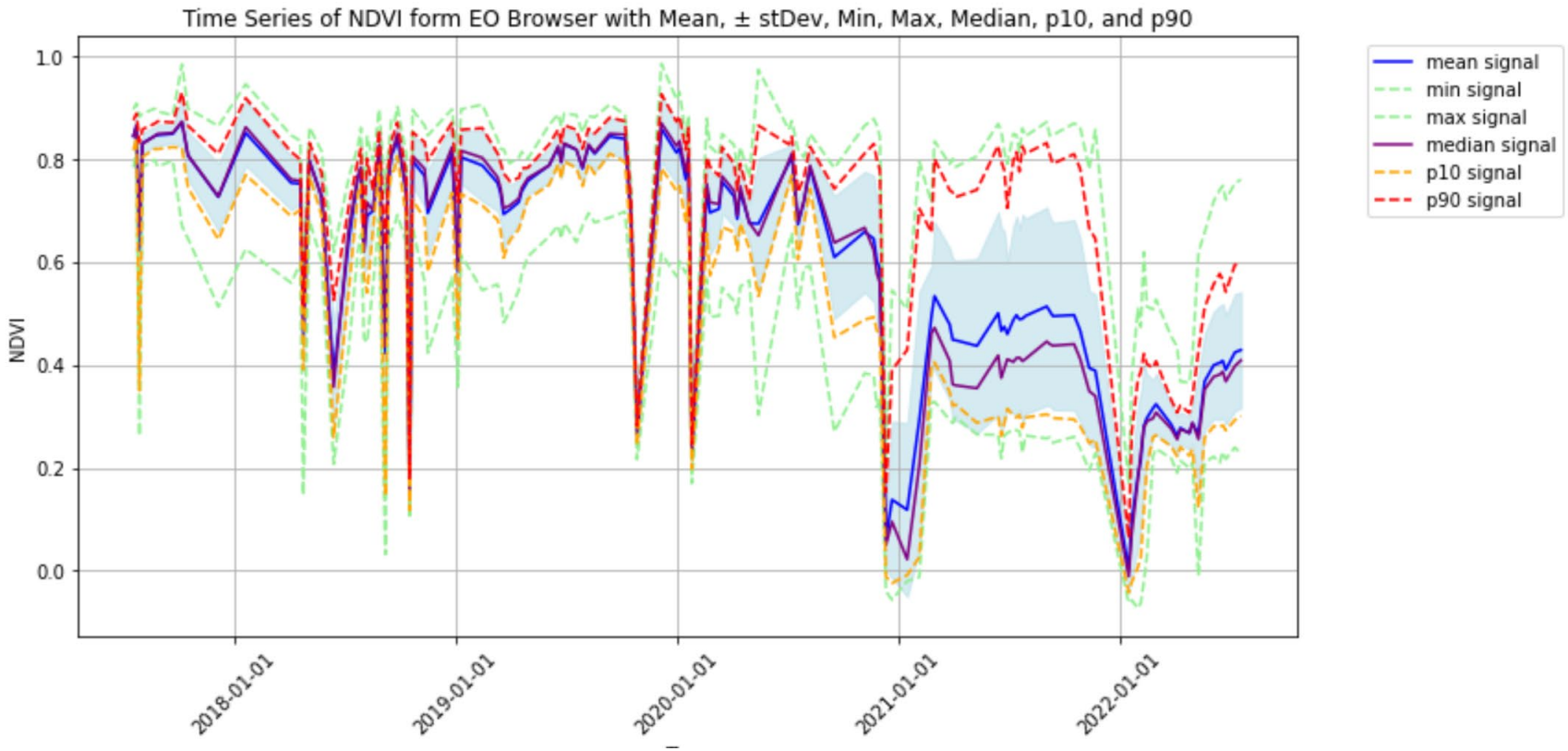
[ ]:
```
# Libraries
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
from scipy.signal import savgol_filter
```

Loading and Analyzing NDVI Data

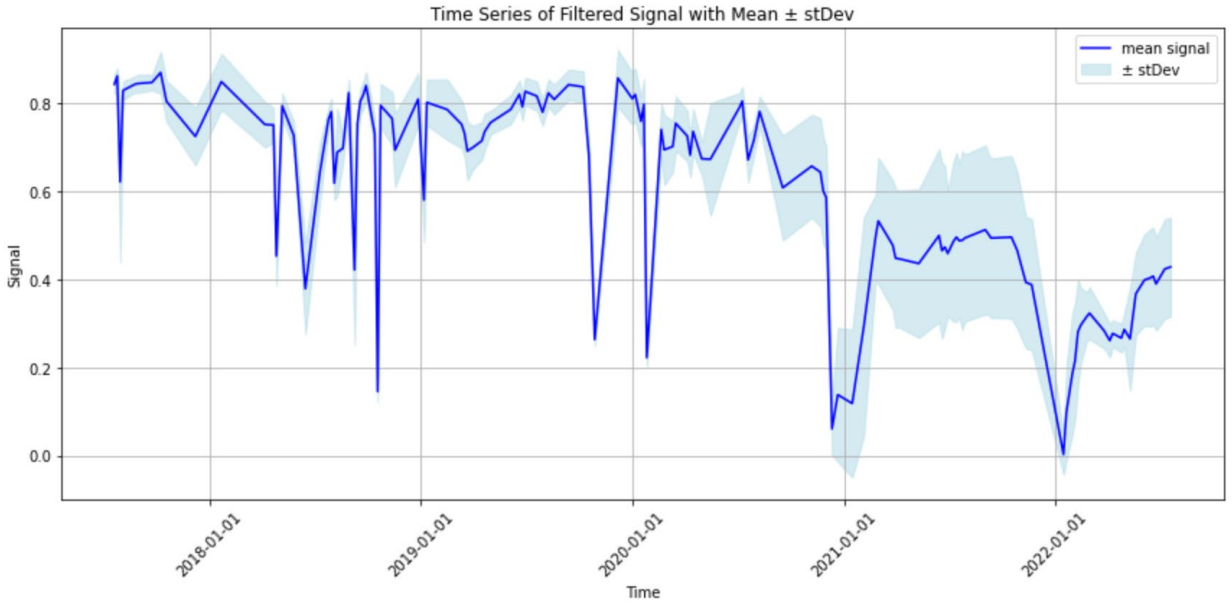
We begin by loading the dataset into a Pandas DataFrame. The 'pd.read_csv' function is used for this purpose. We specify the 'index_col' parameter as 'C0/date' to set the date column as the index, and we also use 'parse_dates=True' to parse the date

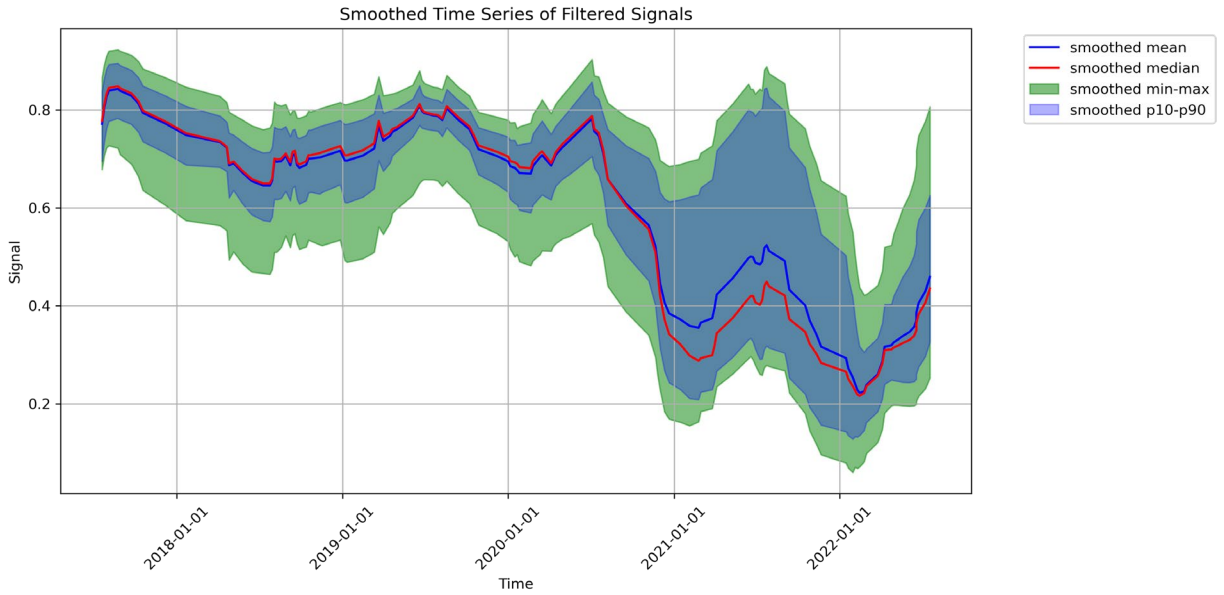
[3]:
```
# Load your DataFrame from the CSV file 'NDVI_S2_example.csv'
df = pd.read_csv('data/NDVI_S2_example3.csv', index_col='C0/date', parse_dates=True)
```

Visualization of NDVI Time Series Data from EO Browser

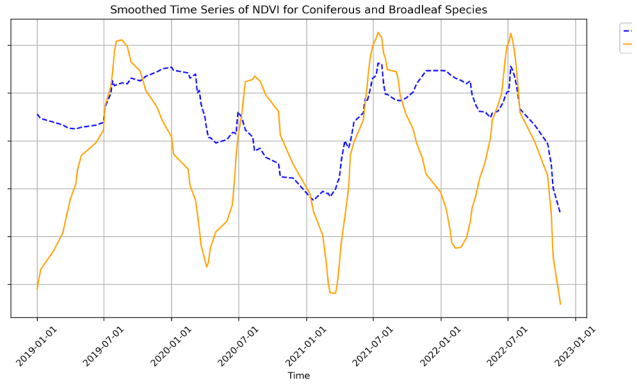


Filtering and smoothing with Savitzky-Golay filter

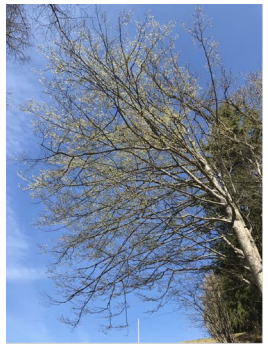


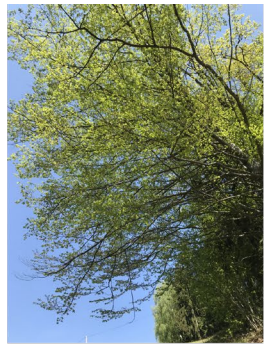


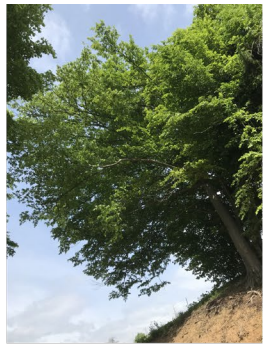
Compare time series of coniferous and broadleaf tree species



- phenology (seasonal changes)
  - Many coniferous species are evergreen, meaning they retain their needles year-round.
  - The deciduous nature of many broadleaf species can lead to significant seasonal variations in their spectral signatures.
- spectral characteristics


11. april 2022

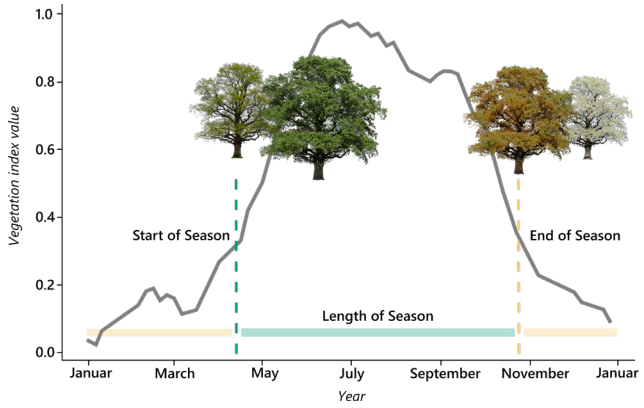

30. april 2022

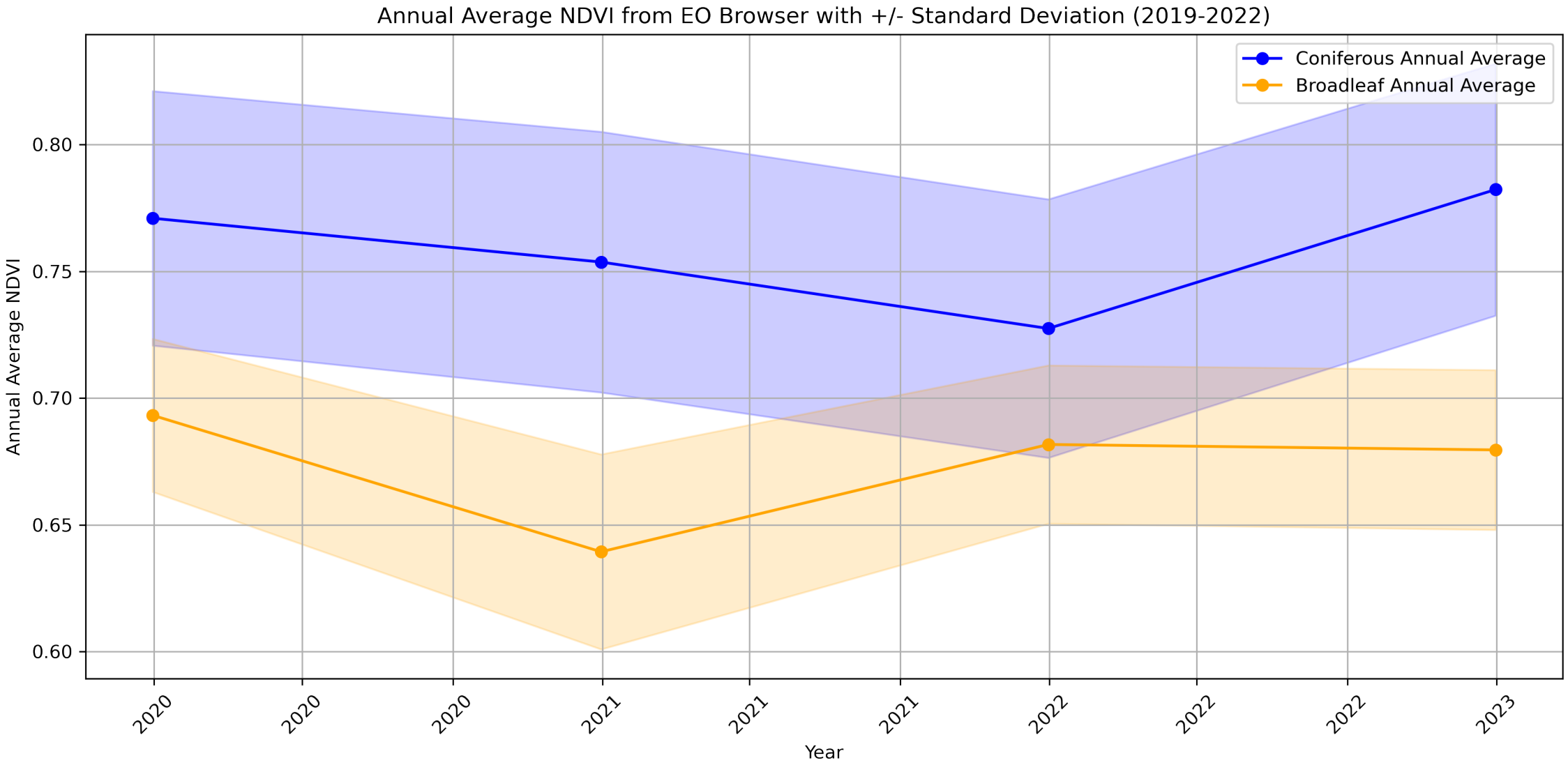

23. maj 2022


19. september 2022


13. oktober 2022

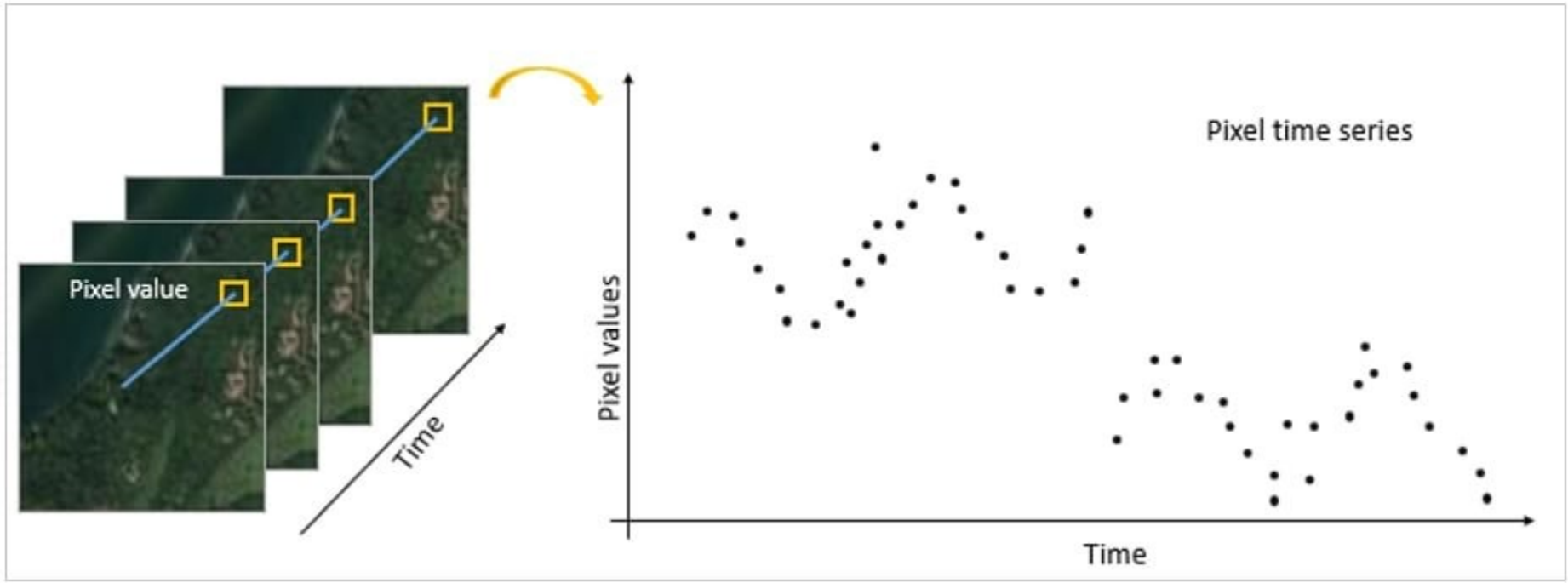

23. oktober 2022




Annual Average NDVI from EO Browser with +/- Standard Deviation (2019-2022)
Coniferous Annual Average
Broadleaf Annual Average
Annual Average NDVI
0.80
0.75
0.70
0.65
0.60
2020
2020
2020
2021
2021
2021
2022
2022
2022
2023
Year

Monitoring Forest Dynamics: Change Detection Using Sentinel-2 Time Series

Change Detection of Time Series Imagery



https://www.esri.com/arcgis-blog/products/arcgis-pro/imagery/change-detection-of-time-series-imagery/

Disturbance Events

- **Abrupt changes** in forests often result from natural or human-induced disturbances, such as wildfires, insect outbreaks, windstorms, or logging operations. These events can lead to sudden alterations in forest structure, species composition, and ecosystem processes.
  - Understanding abrupt changes is critical for assessing the resilience of forest ecosystems.
  - Abrupt changes in species composition can impact biodiversity.
  - Climate change can lead to abrupt changes in forest ecosystems.

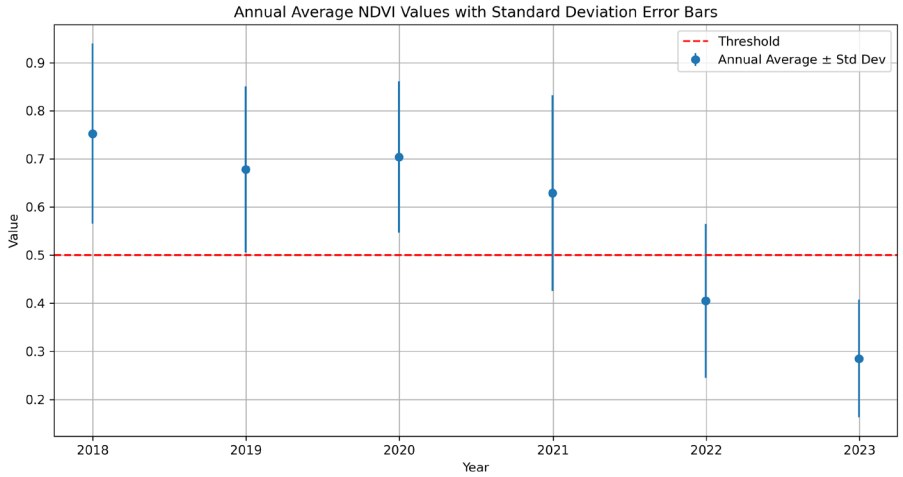
Explore EO Data on EO Browser

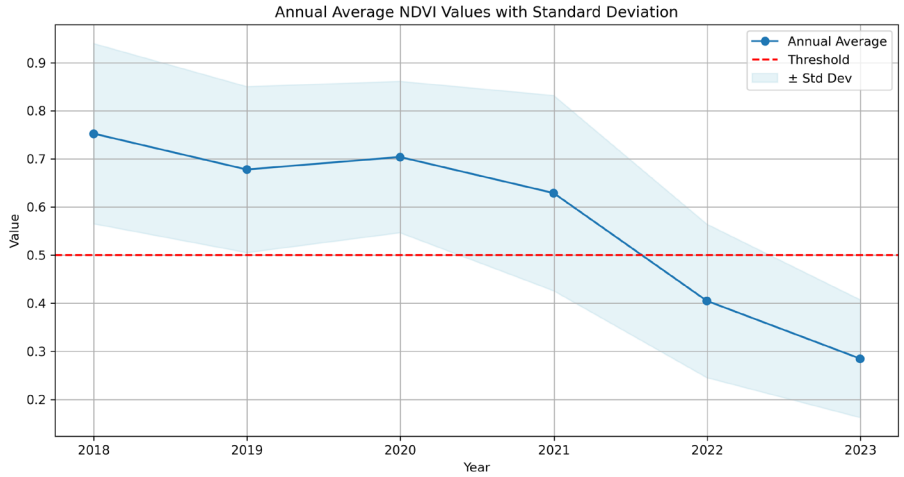
- Find two comparable images from different date, for example
  - 2017-08-24
  - 2022-07-19

Time-lapse

- select AOI
- select EO collection (here Seninel-2 TRUE COLOR)
- select time range and image specification (cloud cover = 0 %)

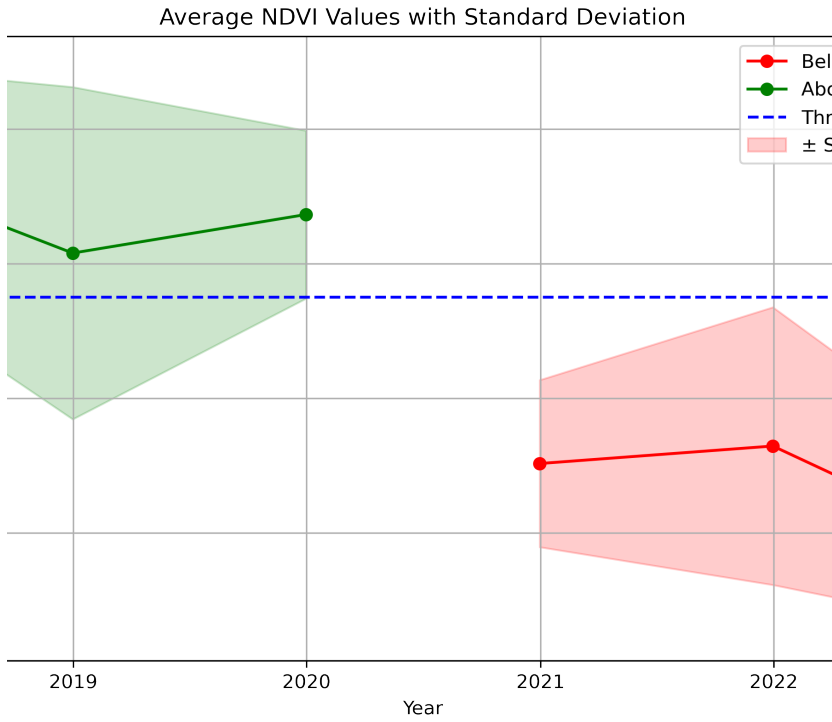
Resample data to identify trends and anomalies with annual values





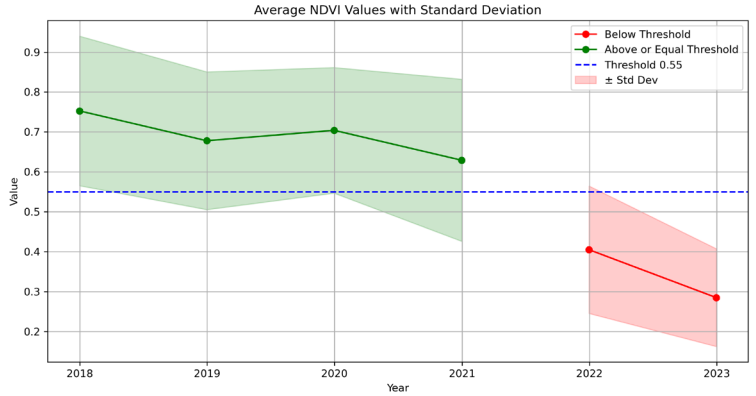
Forest Transformation Due to Windstorm damage

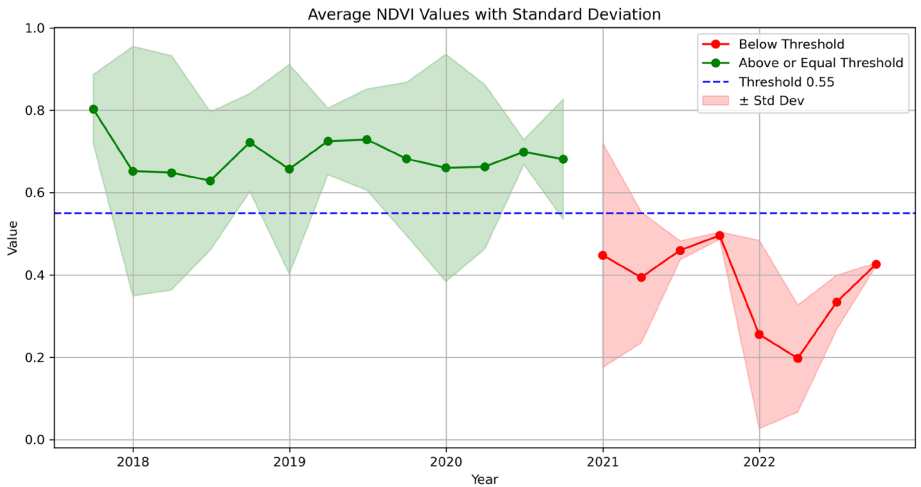
- Sudden changes in land use or forest cover can result in increased runoff and erosion.

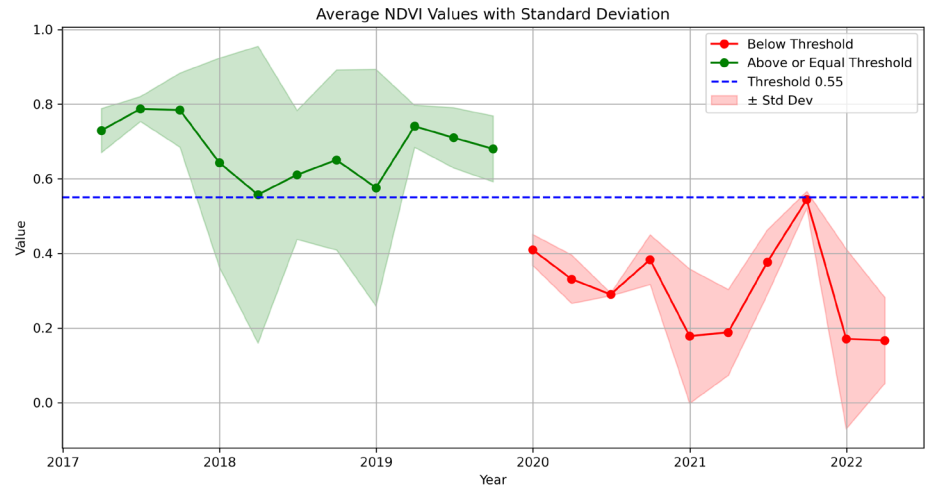


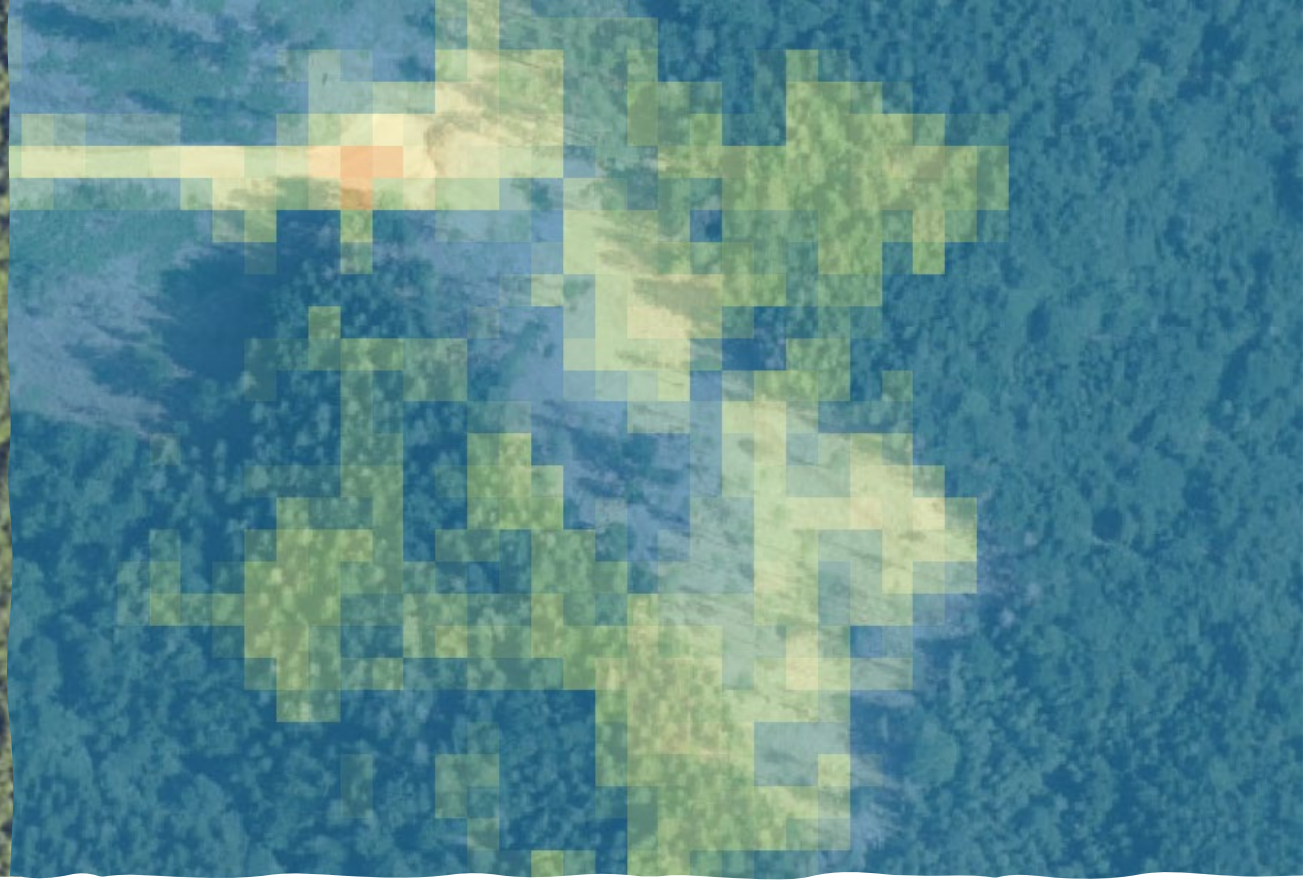
Change detection

- Abrupt changes may signal a loss of resilience, indicating that the ecosystem is vulnerable to further degradation.




Average NDVI Values with Standard Deviation
Below Threshold
Above or Equal Threshold
Threshold 0.55
± Std Dev
Value
Year
1.0
0.8
0.6
0.4
0.2
0.0
2018
2019
2020
2021
2022


Average NDVI Values with Standard Deviation
Below Threshold
Above or Equal Threshold
Threshold 0.55
± Std Dev
Value
Year
1.0
0.8
0.6
0.4
0.2
0.0
2017
2018
2019
2020
2021
2022

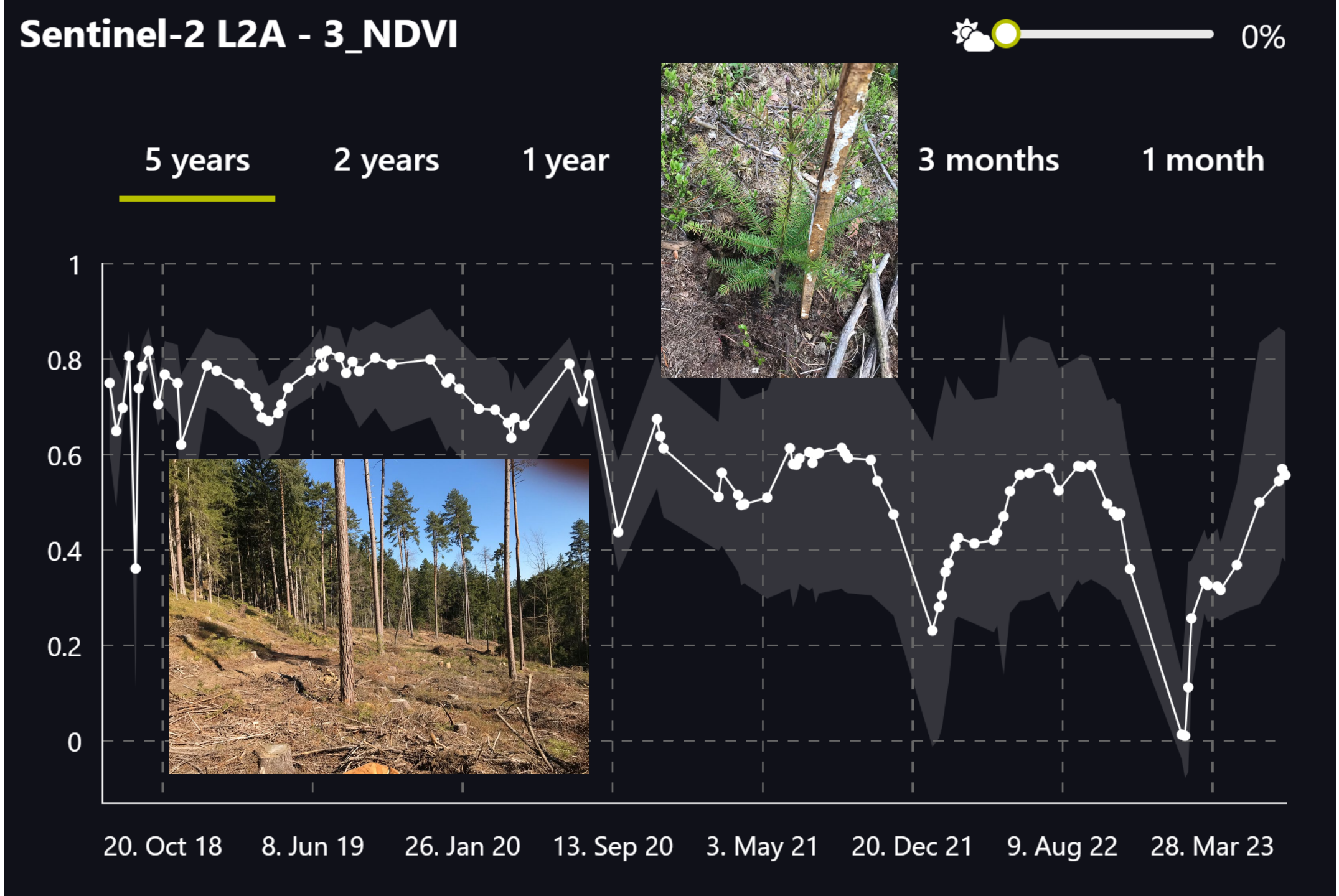


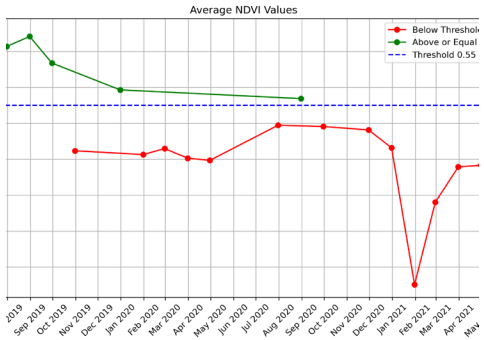
We Can Discover Valuable Insights from NDVI Time Series

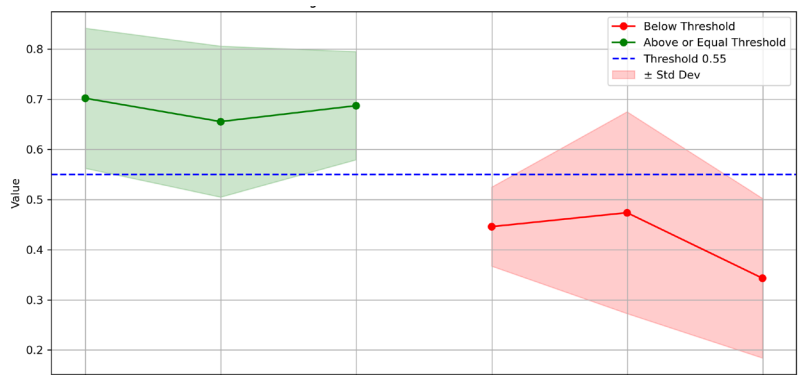
Why Do We Need this Information?

- To assess the extent of damage
- To identify the previous forest type
- To analyze feature trends

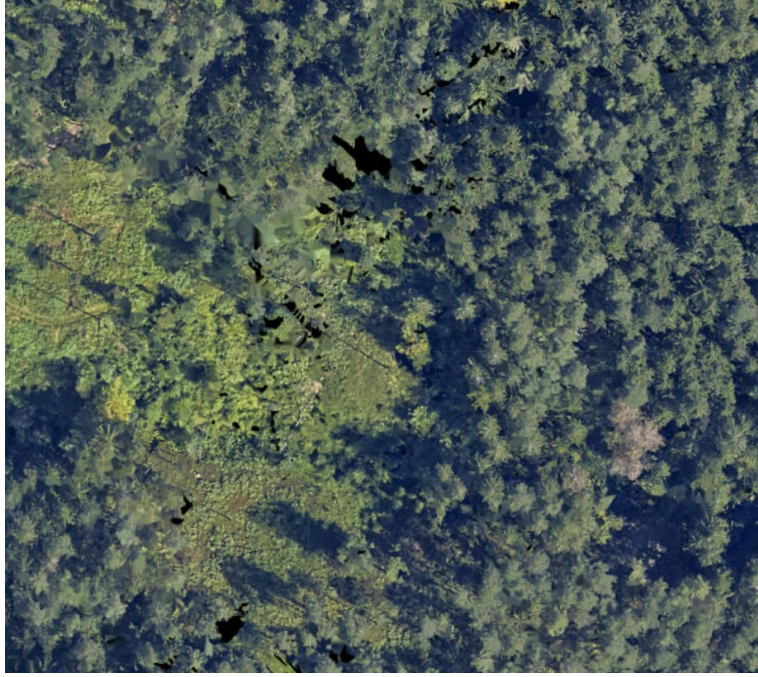
Forest Transformation Due to Bark Beetle Infestation

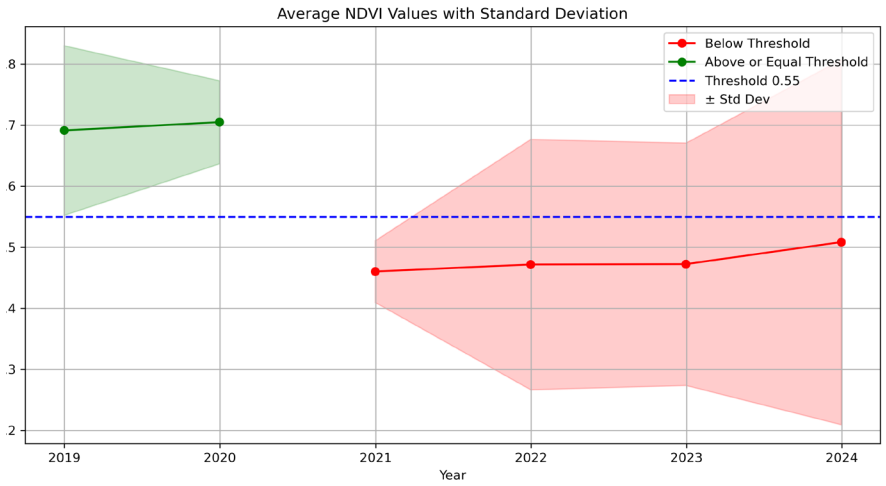

Sentinel-2 L2A - 3_NDVI
0%
5 years
2 years
1 year
3 months
1 month
1
0.8
0.6
0.4
0.2
0
20. Oct 18
8. Jun 19
26. Jan 20
13. Sep 20
3. May 21
20. Dec 21
9. Aug 22
28. Mar 23


Average NDVI Values
Below Threshol
Above or Equal
Threshold 0.55
Sep 2019
Oct 2019
Nov 2019
Dec 2019
Jan 2020
Feb 2020
Mar 2020
Apr 2020
May 2020
Jun 2020
Jul 2020
Aug 2020
Sep 2020
Oct 2020
Nov 2020
Dec 2020
Jan 2021
Feb 2021
Mar 2021
Apr 2021


Below Threshold
Above or Equal Threshold
Threshold 0.55
± Std Dev
Value
0.8
0.7
0.6
0.5
0.4
0.3
0.2

Abrupt changes in species composition can impact biodiversity.





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Forest Management Considerations:

- **Critical for Sustainable Management**

Understand the consequences of forest management activities

Ensure sustainable forest management practices

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Early Warning Systems:

- **Mitigating Disturbances**

Use early warning systems to reduce the impact of disturbances

Proactive measures to protect forests

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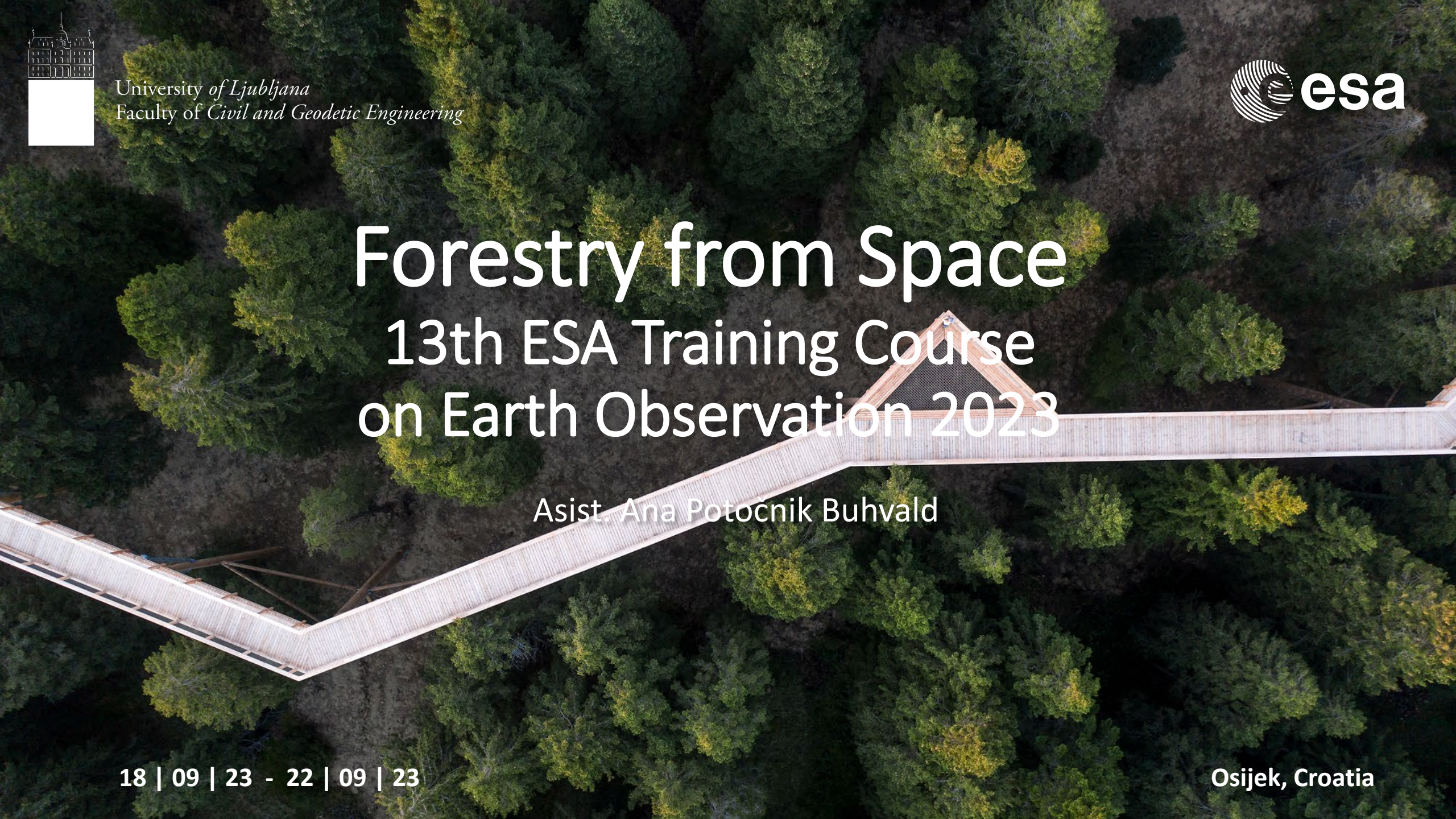
Balancing Conservation and Economics:

- **Key for Success**

Vital for achieving a balance between conservation and economic objectives

Optimize forest management for long-term benefits



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Forestry from Space

13th ESA Training Course on Earth Observation 2023

Asist. Ana Potočnik Buhvald

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