



EXERCISE 6 – TUTORIAL

Precision agriculture mapping – digital image analyses using Sentinel-2 multispectral data, image classification, comparison with UAV multispectral data, using SNAP software

1 | Exercise outline

In this exercise, we will:

- Delve into the use of Copernicus multispectral data in optimizing agriculture mapping
- Explain how to use Sentinel-2 data to monitor plant health and soil conditions
- Learn to process and interpret this data, using indicators like the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Moisture Index (NDMI)
- Compare Sentinel-2 outputs with high-resolution UAV multispectral data

2 | Background

Precise agriculture using Sentinel-2 data

Sentinel-2 satellites are instrumental in precision agriculture due to their ability to provide detailed and frequent multispectral imagery. These images offer valuable insights into crop health, soil moisture, and vegetation growth, enabling farmers to optimize their agricultural practices. In precision agriculture, commonly used indices derived from Sentinel-2 satellite imagery include:

- **NDVI:** Measures vegetation health and vigor based on near-infrared and red light reflectance.
- **EVI:** An improved version of NDVI that corrects for atmospheric effects and provides better sensitivity to vegetation changes.
- **SAVI:** Adjusts NDVI to account for soil brightness, improving accuracy in areas with sparse vegetation.
- **NDWI:** Quantifies water content in vegetation and soil, aiding in soil moisture monitoring and water stress detection.
- **LAI:** Measures leaf area per unit ground area, providing insights into vegetation density and biomass accumulation.

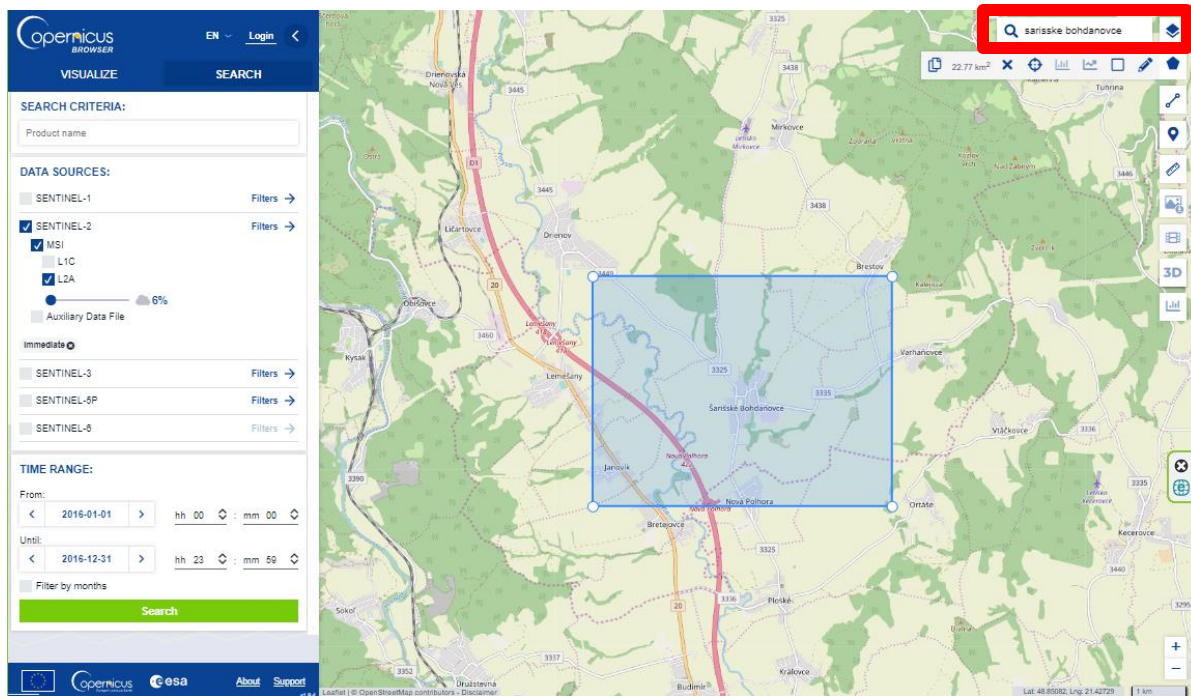
These indices help farmers and land managers monitor crop health, predict yields, and make informed decisions for optimal agricultural practices.



Source: <https://eos.com/blog/precision-agriculture/>

2.1 Study area and data used

For this exercise, we will use three Sentinel-2 images of the same area in Šarišské Bohdanovce, Slovakia, using the Tile Number *34UEV* downloaded for four time intervals in 2016 from the Dataspace Copernicus Open Access Hub [[@https://dataspace.copernicus.eu/](https://dataspace.copernicus.eu/)]. At the end of this exercise, we will compare these Sentinel-2 data with UAV data acquired in September 2016.



2.2. SNAP - Open and explore product

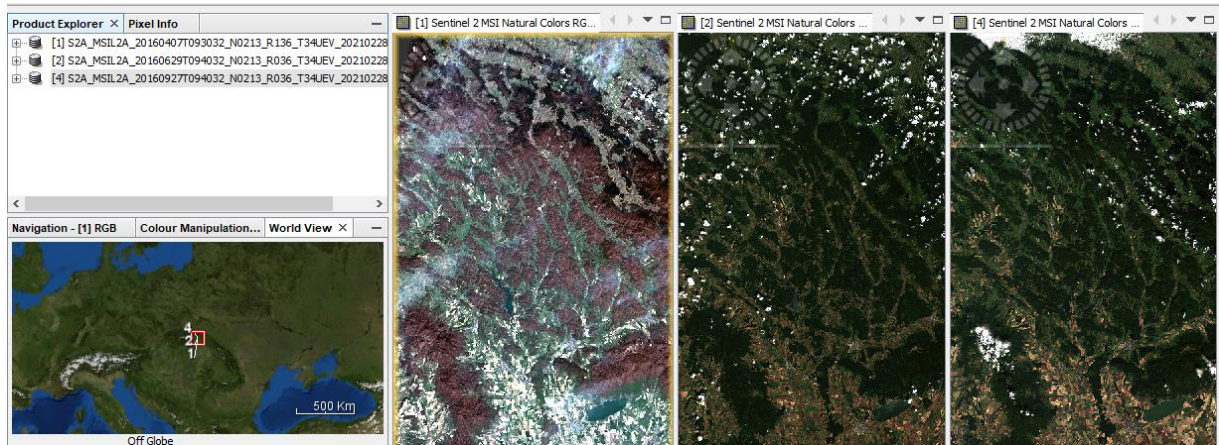
Open SNAP Desktop, click Open Product and open 4 downloaded products (unzipped) by double click on the metadata „MTD_MSIL2A.xml“ inside the folder. The opened products will appear in Product Explorer window.

```
S2A_MSIL2A_20160407T093032_N0213_R136_T34UEV_20210228T161314.SAFE
S2A_MSIL2A_20160629T094032_N0213_R036_T34UEV_20210228T170703.SAFE
S2A_MSIL2A_20160927T094032_N0213_R036_T34UEV_20210228T181146.SAFE
```

Display all products side by side using e.g. Atmospheric penetration band combination: Right click on the product – Open RGB Image Window – select Sentinel 2 MSI Natural colors. Repeat this step also for other two products.

Then, tile windows horizontally. By opening and displaying all 4 images at once, we can take a first visual interpretation of agriculture fields in 2016 - from the left.

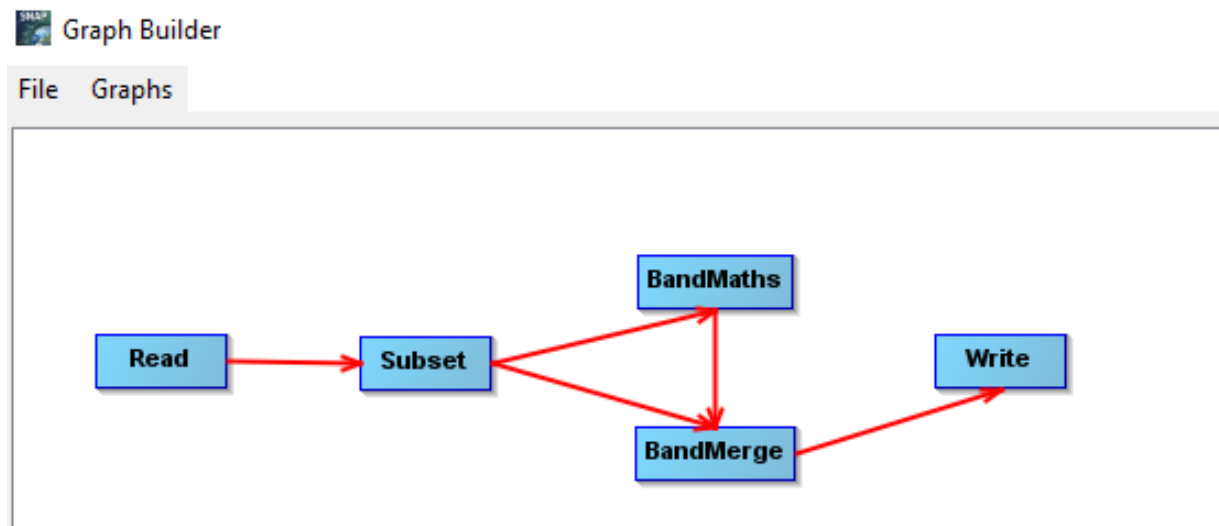
In Navigation tab – Synchronise views across multiple image windows – Zoom into the eastern part of the image to explore deforestation.



2.3 Create Processing Graph

Then, we need apply the same pre-processing steps for all our scenes. However, processing the data step by step and product by product could be time-consuming and impractical. Fortunately, the **Batch Processing** tool in SNAP allows us to apply all the steps to both images simultaneously, saving both time and disk space since only the final product is physically stored.

To use the tool, the initial step is to define the process we intend to apply along with all its corresponding steps. This can be accomplished by utilizing the GraphBuilder tool. Therefore, let's build our graph by navigating to **Tools** → **GraphBuilder**. Through the GraphBuilder function, we build a processing graph, outlining the specific order of processing steps:



At the beginning, the graph has only two operators: **Read** (to read the input) and **Write** (to write the output). To add the new operator right-click the white space between the existing operators and select the desired operators:

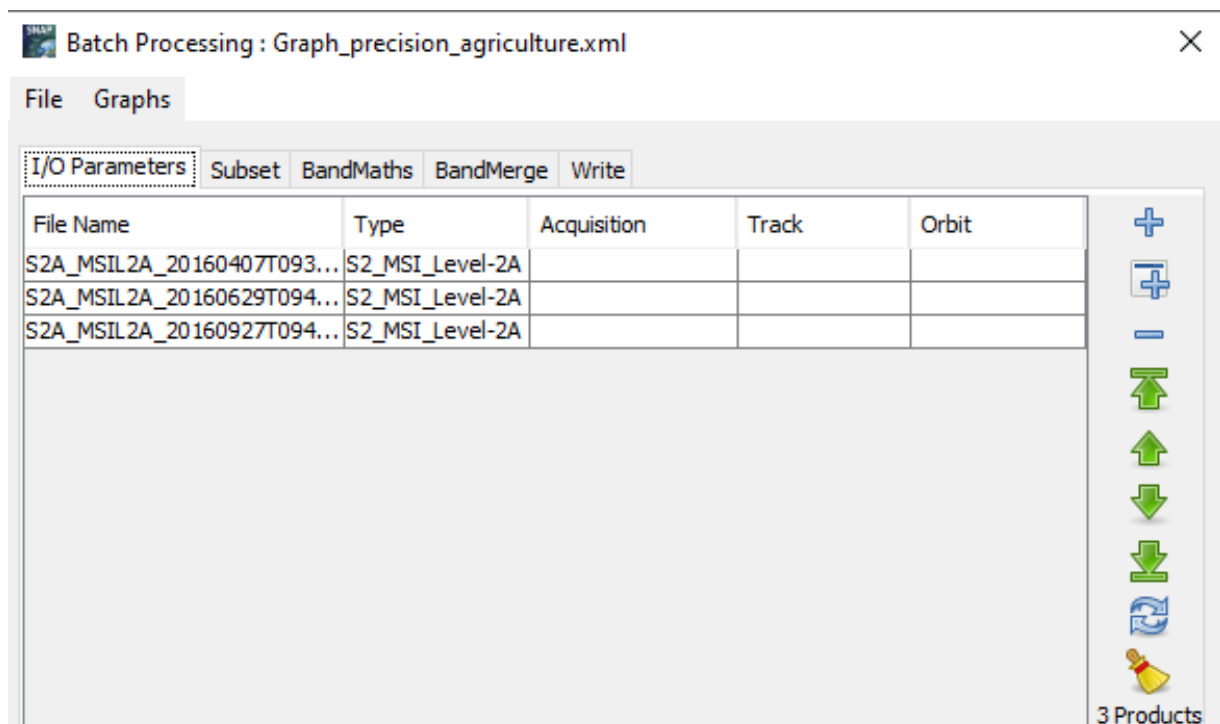
- **Subset** – export only bands that we will need for further analysis to calculate NDVI, GNDVI, GRVI – select only B3, B4 and B8
- **Band Maths** – to calculate NDVI, GNDVI, GRVI using selected bands
- **Band Merge** – to combine the resulting bands into the resulting file

For the moment, do not change anything in the parameter tabs and save the graph (File – Save Graph) as „Graph_precision_agriculture.xml“ to your working folder. After you have saved it, close the GraphBuilder window.

2.4 Batch Processing

Open the **Batch Processing tool** (Tools → Batch Processing).

We will add all opened products by clicking Add Opened on the upper right (second icon from the top). Then, we delete original = not projected products by selecting them and clicking Delete (third icon from the top left only reprojected products). Then, when we have only 4 reprojected products, we click File - **Load Graph** at the top of the window and navigate to our saved graph „Graph_Deforestation“ and open it. We see that new tabs have appeared at the top of window corresponding to our operators with the exception of Read; this is correct as these parameters will be set in the I/O Parameters tab.

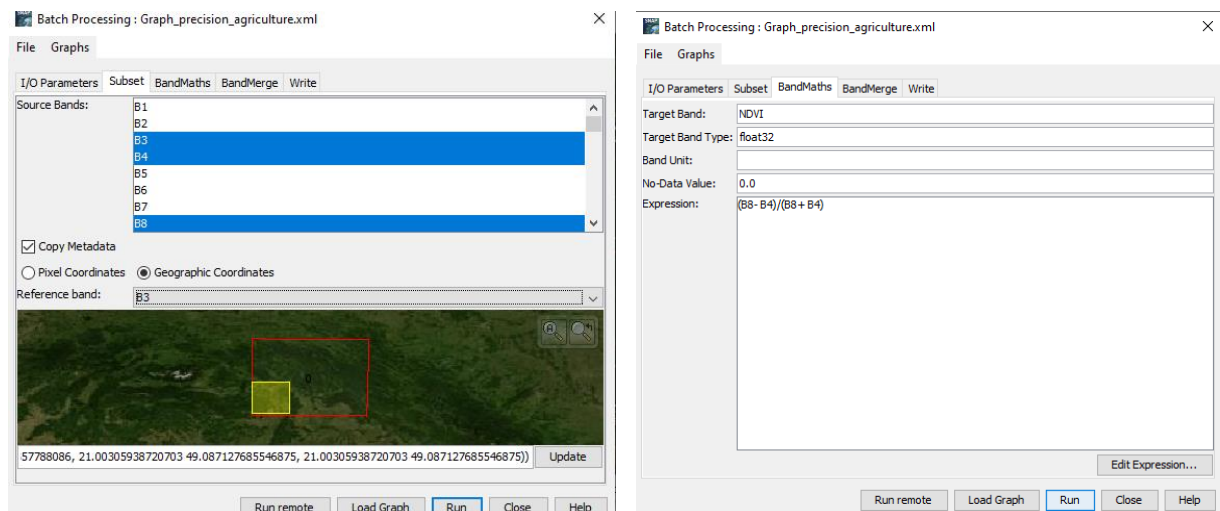


In the next step it is advisable to create **Subset** of these products for faster processing:

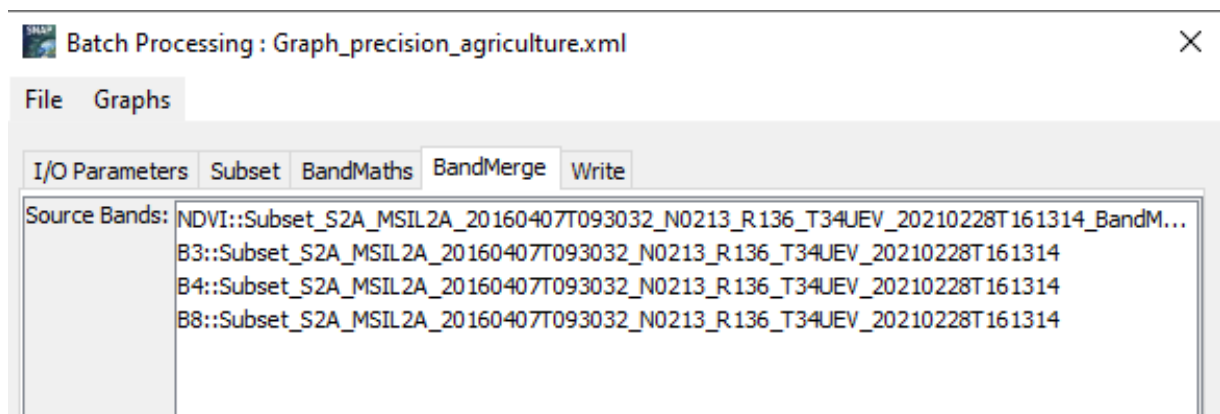
- **Source bands** – select only bands that we will need to calculate NDVI – B3, B4 and B8
- **Geographic Coordinates** – create the subset of the area also by clicking on zoom into the area of image (red rectangle) and draw smaller (yellow) polygon inside it that includes only eastern part of the images where we observed deforestation
- **Reference band** – select Reference band according which all the Source Bands will be resampled

In BandMath, we firstly enter the formula for NDVI calculation. The NDVI is calculated as a normalized difference of visible infrared (B8) and visible red (B4) bands, using the following equation (Rouse et al. 1974):

$$(B8-B4)/(B8+B4)$$



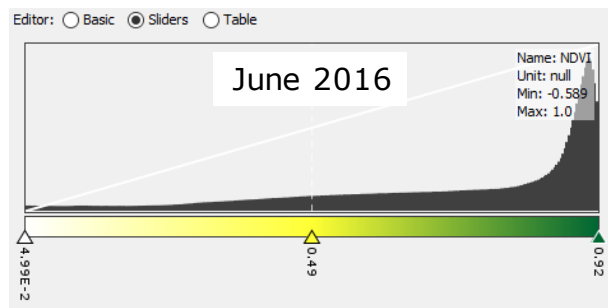
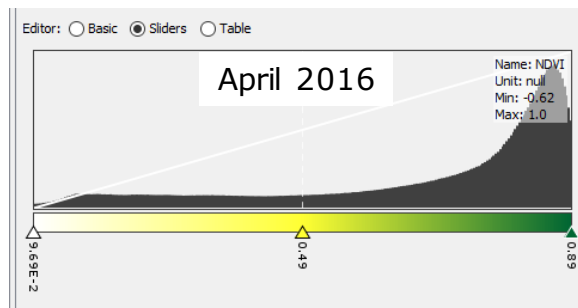
Then, in **BandMerge** tab we can combine the resulting bands into the resulting file and set the directory for the output file in **Write** tab. The common processing can be monitored. Writing target product may take some time.



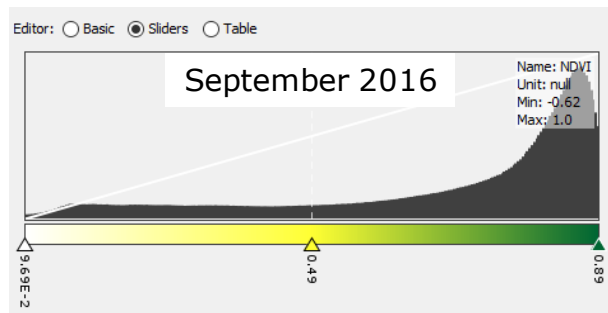
3.1. NDVI analysis

Open the output NDVI images side by side for all processed years – **Window – Tile Horizontally**. In Colour Manipulation select Colour ramp derived from meris pressure.

NDVI image - has values from $< -1, 1 >$, where forested areas are displayed in values higher than 0. The peaks of the histogram point to 2 extremes - forested and logged area.



The highest NDVI values occurs in the summer season – June - during periods of peak vegetation growth and vigor. NDVI values tend to increase as vegetation biomass and chlorophyll content rise, reaching their peak when vegetation is at its most lush and dense.



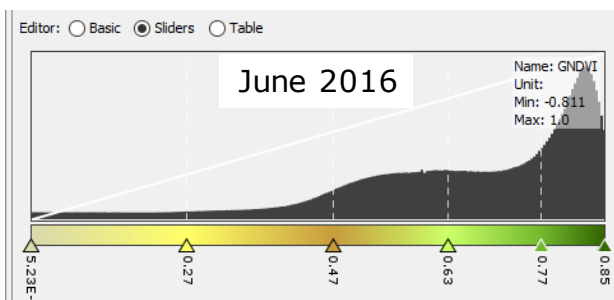
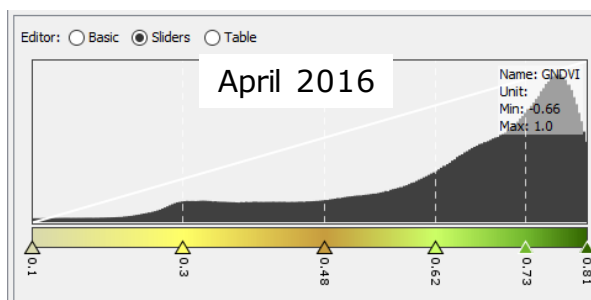
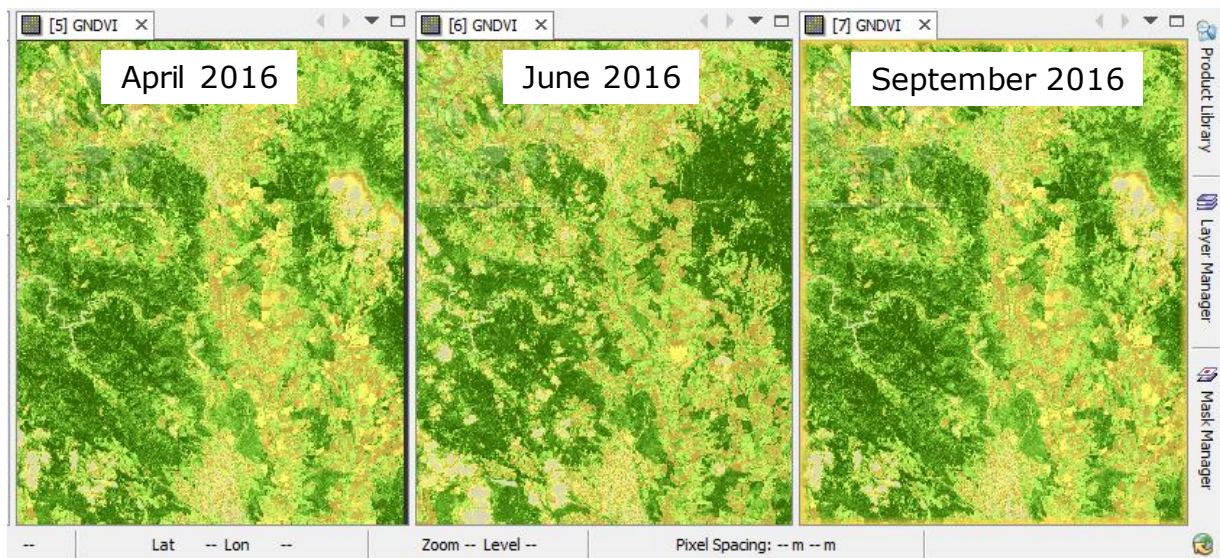
Lower Normalized Difference Vegetation Index (NDVI) values occur at the beginning of the growth season – April and during periods of reduced vegetation activity in September - a decline in NDVI values may exhibit also reduced chlorophyll content or structural damage, affecting its reflectance properties.

3.2 GNDVI analysis

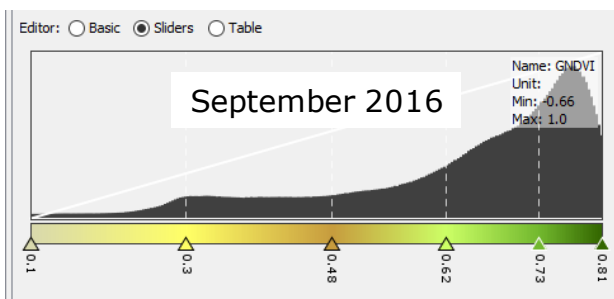
Create the GNDVI. Use the resulted subsets. Navigate to the Main menu – Raster - Band Maths and edit formula as following:

$$\text{GNDVI} = (\text{NIR} - \text{Green}) / (\text{NIR} + \text{Green})$$

Click on RUN. Then, firstly open the output GNDVI images side by side for all processed years – **Window – Tile Horizontally**. In Colour Manipulation select Colour ramp derived from meris pressure.



GNDVI values typically range from -1 to 1, with higher values indicating healthier and more dense vegetation. Values close to 1 indicate strong vegetation presence, with dense and healthy vegetation exhibiting the highest values. Values close to 0 suggest sparse vegetation or non-vegetated areas. Negative values may occur in features such as water bodies or shadows.

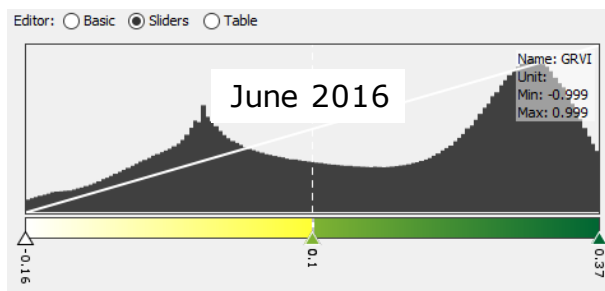
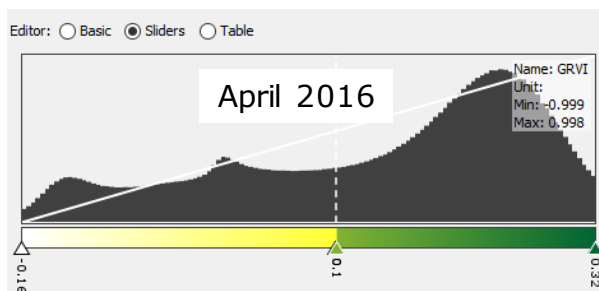


3.3 GRVI analysis

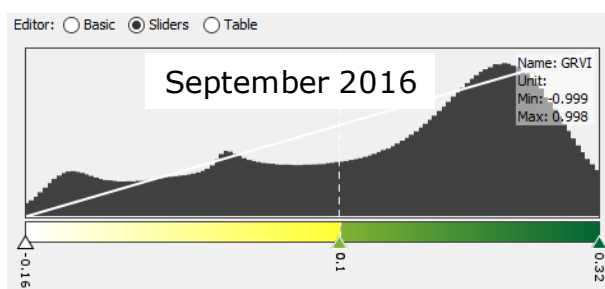
Create the GRVI. Use the resulted subsets. Navigate to the Main menu – Raster - Band Maths and edit formula as following:

$$\text{GRVI} = (\text{Green} - \text{Red}) / (\text{Green} + \text{Red})$$

Click on RUN. Then, firstly open the output GRVI images side by side for all processed years – **Window – Tile Horizontally**. In Colour Manipulation select Colour ramp derived from meris pressure.



GRVI index can differentiate between green vegetation (index above 0), water and snow (index around 0), and soils (index below 0). Additionally, unlike the NDVI, the GRVI is sensitive to changes in leaf color, making it effective for detecting shifts in vegetation phenology.

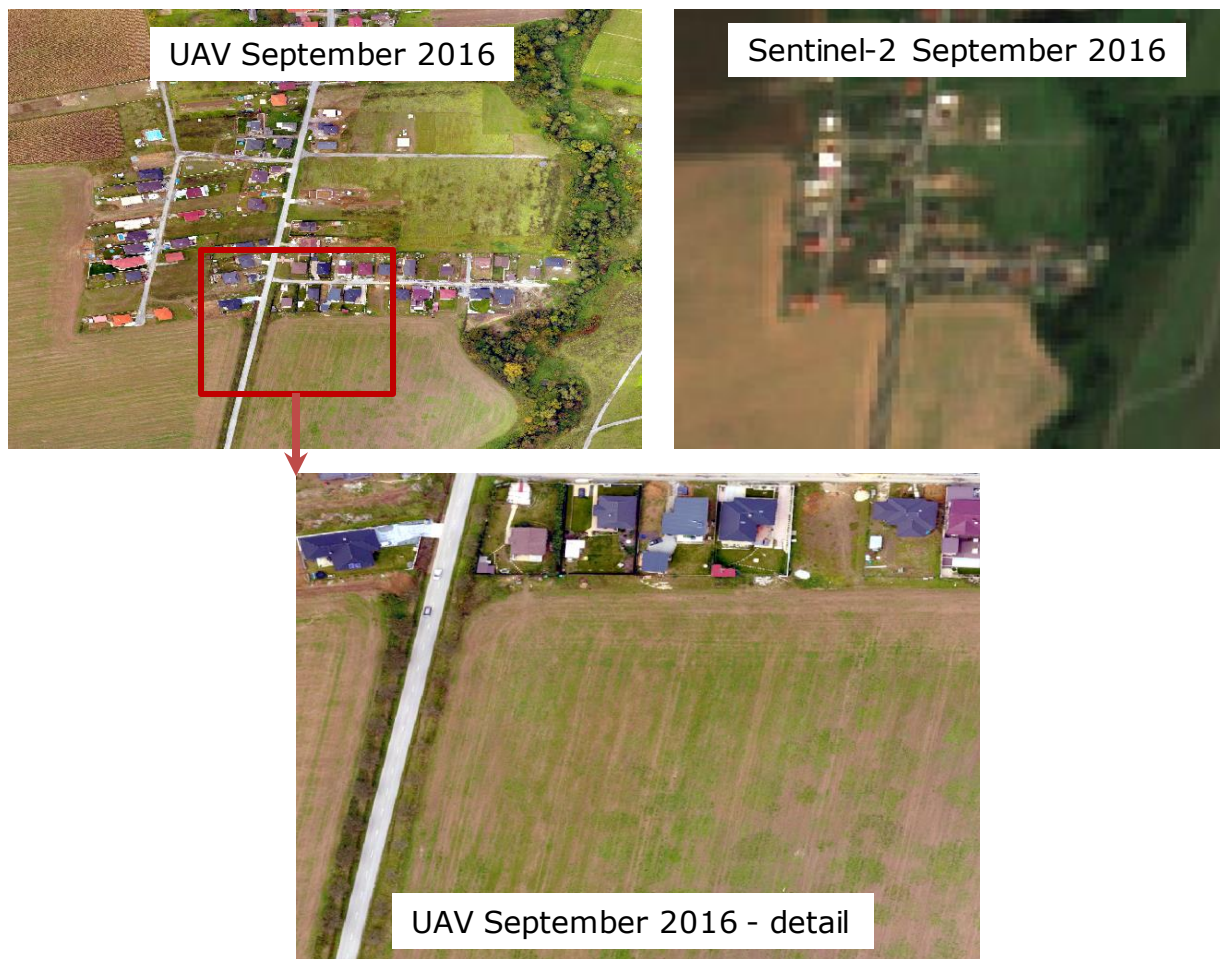


4. Comparison of UAV data with Sentinel-2

In QGIS open the sample data for the smaller area of interest within the locality of Šarišské Bohdanovce. Compare high spatial resolution of UAV data compared to Sentinel-2 multispectral data.

UAV data offer high spatial resolution and flexibility, making them suitable for detailed and targeted assessments of small areas. UAVs have revolutionized, e.g. precise agriculture by providing farmers and agronomists with timely, accurate, and actionable information for optimizing crop production, resource management, and decision-making processes. With their ability to collect high-resolution spatial data efficiently and cost-effectively, UAVs are increasingly becoming indispensable tools in modern agriculture.

On the other hand, Sentinel-2 satellite data provide consistent and systematic coverage over larger regions, offering valuable insights into broader landscape dynamics and long-term trends. The choice between UAV and Sentinel-2 data depends on the specific requirements of the application, considering factors such as spatial scale, temporal frequency, cost, and accessibility.



THANK YOU FOR FOLLOWING THE EXERCISE!