Course title: EOTIST Standard course

Course subject: Remote Sensing

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LESSON SR4 - EXERCISE
SPECTRAL INDICES

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Learn about reflectance principles

Compute spectral indices

Use spectral indices for burned area detection

KEY ELEMENTS

Spectral signature, vegetation, bare soil, spectral bands

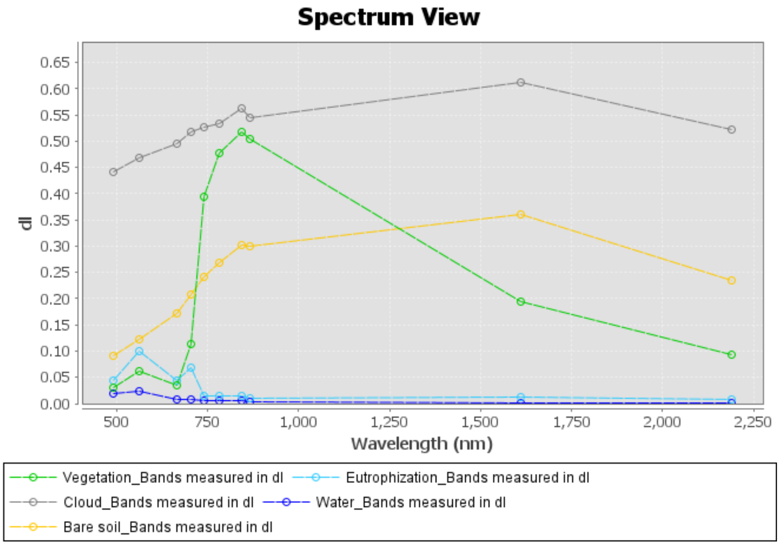
SOFTWARE

SNAP

DATA

Sentinel-2MSI L2A images from Catalonia

1. INTRODUCTION



This exercise is focused on the calculation of environmental metrics and phenomenon gathered by remote sensing satellites, and computed through basic algebra operations. The implementation of spectral indices is based on the different reflectance values that different earth surfaces (included living surfaces) produce to the different radiation wavelengths.

Spectral indices are widely used in land surface monitoring, such as agricultural production (vegetation) flood detection (water), burned area and ecosystem metrics, such as primary production or energy exchange.

This exercise is a guide to generate the main spectral indices, and to compute pixel based indices using the raster calculator of SNAP. (NDVI, SAVI, NBR)

SNAP software can be downloaded in https://step.esa.int/main/download/snap-download/

The materials for this exercise are Sentinel 2 Atmospherically corrected images (L2A) subsetted for a Spainish region and down sampled from 10 to 20 m of pixel size. This images have been exported to SNAP native format BEAM-DIMAP.

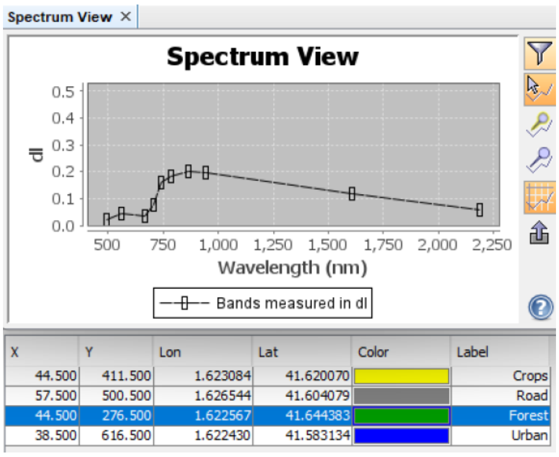
Source images cover part of north-eastern area of the Iberian Peninsula, and the temporal range is between 06-07-2015 and 24-09-2015, before and after a forest fire. Images were selected because of the proximity to the fire date (15-07-2015) and the low cloud contamination (although they are not free from it). This exercise aims to reproduce part of the materials used in:

García-Llamas, P., Suárez-Seoane, S., Fernández-Guisuraga, J. M., Fernández-García, V., Fernández-Manso, A., Quintano, C., Taboada, A., Marcos, E., & Calvo, L. (2019). Evaluation and comparison of Landsat 8, Sentinel-2 and Deimos-1 remote sensing indices for assessing burn severity in Mediterranean fire-prone ecosystems. International Journal of Applied Earth Observation and Geoinformation, 80, 137-144. https://doi.org/10.1016/j.jag.2019.04.006

2. PHISICAL PRINCIPLES

Open rasters in SNAP:

Open '*S2A_MSIL2A_Catalonia_06072015.dim*' and '*S2A_MSIL2A_Catalonia_24092015.dim*' in a new SNAP session (File -> Open Product ->…). Plot the image by right-clicking on the Product explorer object and select Open RGB image window. Select the correspondent bands for a true colour visualization (for sentinel 2: B=2, G=3, R=4). Nevertheless, you can play with other visualizations.



Take a first sight and try to find this different covers:

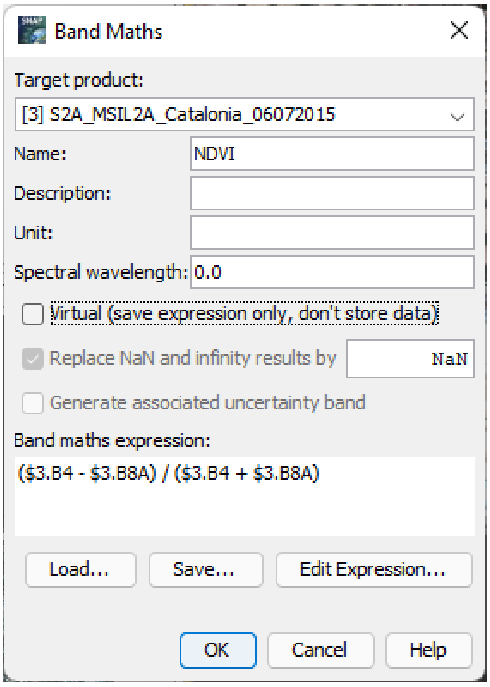
- Crops
- Urban Area
- Bare rocks
- Roads

Click in the pin placing tool in the main toolbar and add a pin at each land cover detected. Try to place it in "pure" pixels. Go to View ->Tool windows -> Pin manager, and change pin label and colours, in order to identify each pin to its land cover. Click on optical -> Spectrum View. This tool displays image reflectances for each spectral band at a pixel scale. Move the cursor abroad the image and check different spectral signatures. Try to identify those containing the red edge pattern, and the intensity of it.

In the spectrum view window, activate "Show spectra for all pins" icon. Now the spectral signatures for the identified covers is displayed. Can you identify the red edge pattern in the forest and crop covers? If you can't identify it in the crop cover, why do you think it is lacking?

3. VEGETATION INDICES

As you know, Vegetation Indices are based in this red edge effect to distinguish photosynthetically active vegetation. Using the correct arithmetic expression with the spectral bands situated in the bottom and the top of the curve, this effect can be maximized.



As these are simple operations, with few parameters and easy to calculate in terms of computation, SNAP provides a module to produce some of the most common spectral indices, such as NDVI and SAVI.

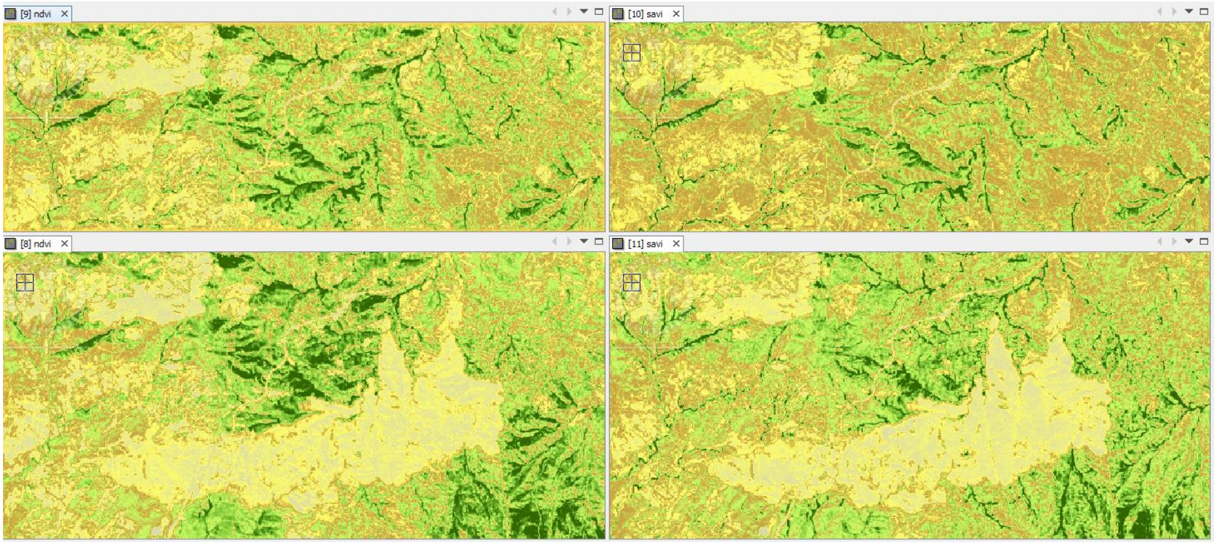
Go to Optical -> Thematic Land Processing -> Vegetation Radiometric Indices -> NDVI Processor.

Select the source and the target name (default is ok). In Processing parameters, leave both Red and NIR default (1.0). Set Red source band to B4 and NIR source band to B8A and Run the process. Repeat NDVI calculation for the other layer, and repeat both calculations but for SAVI Index. Set the correct bands to the processing parameters, and set L = 0.5.

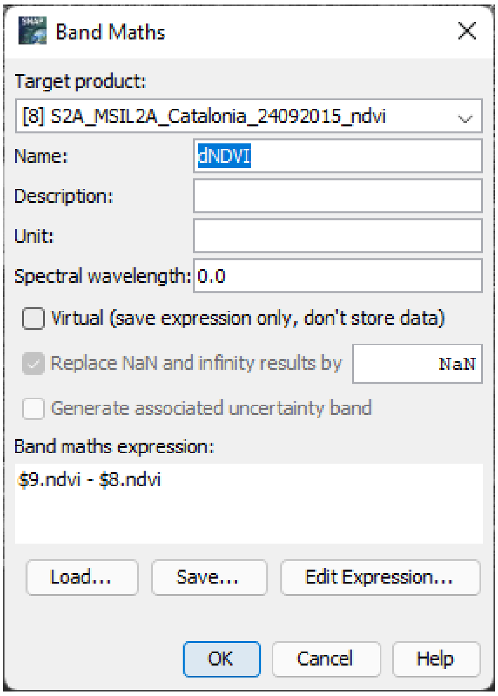
These calculations can also be done in the Band Math in the Raster menu, writing the correct expression: *($3.B4 - $3.B8A) / ($3.B4 + $3.B8A).* Maybe you will have to change the number rght after the $ sign, as this is just to link the raster source. Remember this point for later operations.

Display the four vegetation indices and check for the main differences between dates ans vegetation indices. Which is the biggest difference betweentes? And between spectral indices?

To display the images, display the vegetation indices bands and close the previously displayed. Then, Click on Window -> Tile evenly and reorder the bands position by dragging the tabs in a visual way (i. e. dates in rows and indices in columns). You can also change colour ramp in the Colour Manipulation, Basic editor, window (lower left).



4. BURNED AREA



As you can see, the lower values patch present in the second date images correspond to burned area. Nevertheless, lower values other than the ones in the fire shape are also present. In order to minimize this effect and distinguish the biggest decrease in the vegetation activity, the subtraction of the last to the first date is performed. Use the Band Math tool in the Raster menu to calculate these subtractions. Name the new bands dNDVI and dSAVI. Use the “Edit expression” window, and set the correct operation using the different Product and Data sources. Untick the “Virtual” option before running the operation.

Display the new images the same way the previous mosaic was displayed (…. Tile evenly). A part from the high values in the burned area, there is also an artefact in the lower right. Could you guess which is the origin of the high dNDVI and dSAVI values in this area? Check the true RGB combinations. Think also about the possible issues of combining images with high time-lag, particularly in very steep terrain.

Using the Pixel Window (View -> Toolbar Windows -> Pixel Info) click on the pixels inside the burned area and try to establish a threshold for burned area, in order to associate higher values to burned areas, and lower values to non-burned areas. Remember to set a margin to the threshold:

- dNDVI threshold value:
- dSAVI threshold value:

In order to distinguish burned areas, specific spectral indices other than vegetation indices can be processed. Now calculate the Normalized Burn Ratio (NBR):

$$NBR = \frac{NIR - SWIR}{NIR + SWIR}$$

Working with Sentinel-2 spectral bands, use B8A as NIR and B12 as SWIR. Use the Band Math tool in the Raster menu, assign “NBR” as the band names and untick “Virtual” option. Do it both dates. This operation can also be performed using the NDVI calculation module, just changing the Red and NIR values to the correct bands.

Display both NBR layers. Does burned areas in NBR have higher or lower pixel values than non-burned areas?

Now calculate dNBR. Do the same operation that was done for dNDVI and dSAVI in the Band Math.

Can you see differences in the visual output among these three different indices? Where can you see them? Which one of these three indices do you think can discriminate better the burned areas?

At last, calculate Relative delta Normalized Burn Ratio (RdNBR, Miller and Thode, 2007), This spectral index is derived from dNBR:

$$RdNBR = \frac{dNBR}{|NBR_{pre}|^{0.5}}$$

Use the Band Math as in the previous calculations. You can find the right functions for the absolute values and the square root in the functions part in the edit expression window. Remember to change the product and the data source to the dNBR and the previous date NBR.

Display evenly tiled the four burn severity indices: dNDVI, dSAVI, dNBR and RdNBR.

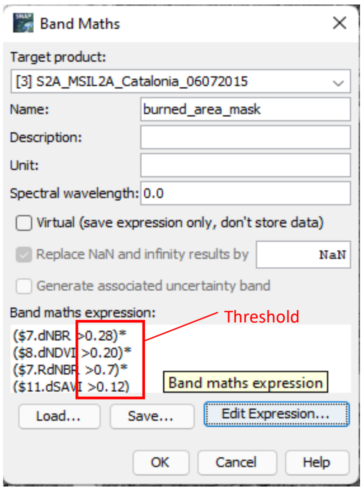
Which index do you think can discriminate better the shadow effects from the steep terrain?

Which index do you think produces more artefacts in the crop areas?

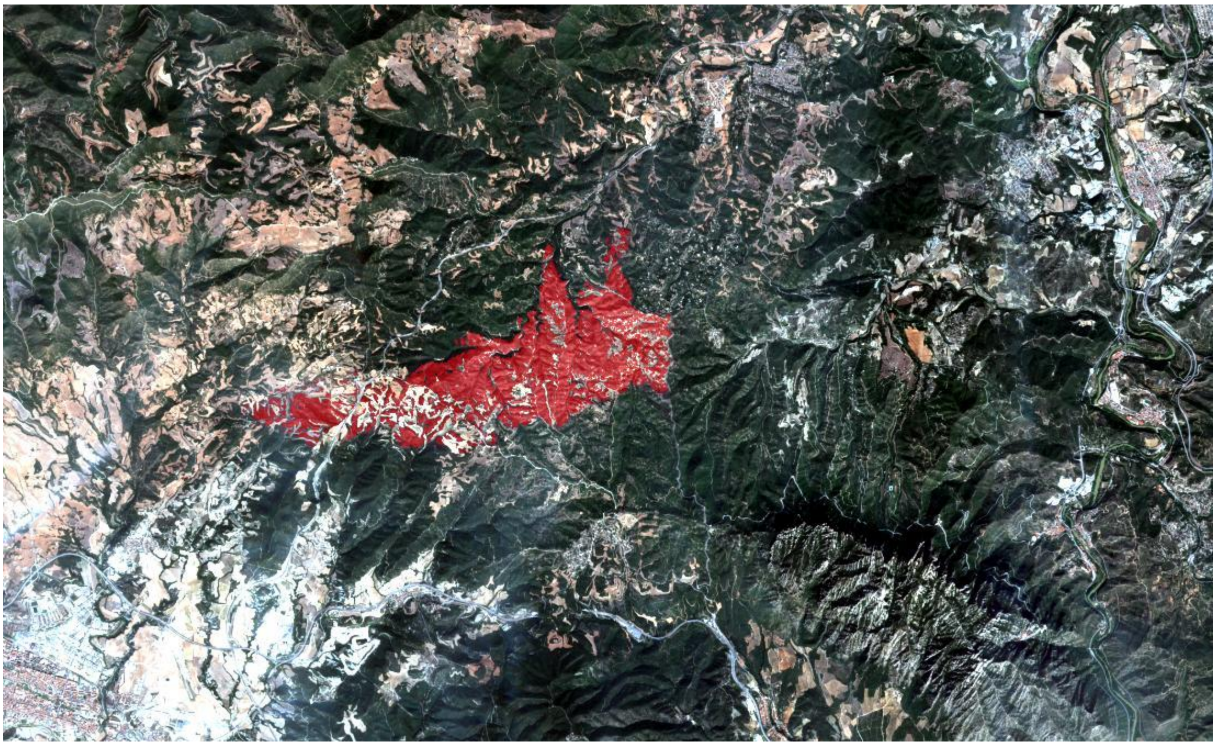
5. ANALYSIS

Now, build a mask layer for the burned area. To do so, use the Band math tool and use the threshold values to select which pixels can be considered as burned. Multiply binary masks and make the burned area mask using the calculated ratios. This exercise will minimize the artefacts (non-burned pixels identified as burned) present in any of the indices calculated, and will only keep the matching pixels. It is necessary then to establish correct thresholds. If at the first try you still see some artefacts, you can readjust the thresholds for any of the indices. Ensure to set the target product in the post fire product (24-09-2015).

Check the visual output to decide if the thresholds are correct. You can look at a specific index artefact and see if it disappears in the mask or it is still present. Also, try to select quite loose thresholds to capture all the real burned area. Plot the burned area mask evenly tiled with the post fire RGB combination.

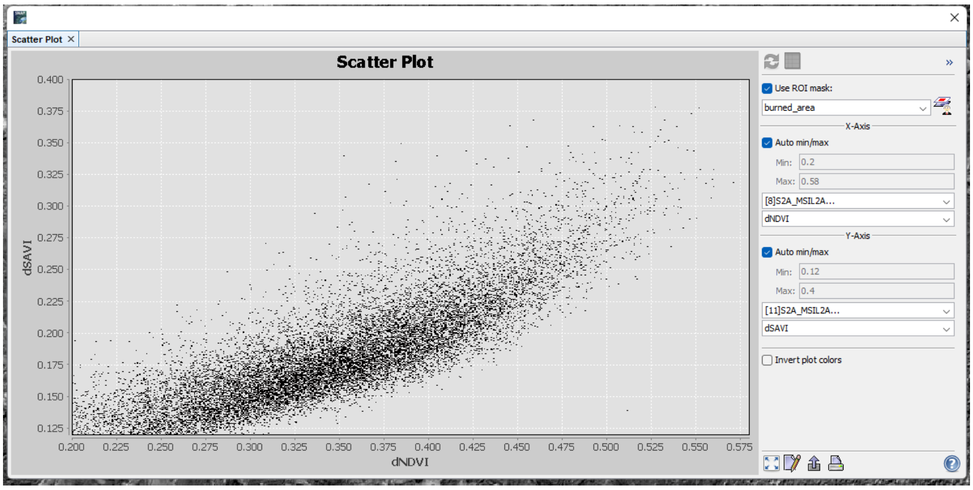


Display the post fire RGB combination. Now, go to the mask manager window (View -> Tool Windows) and create a new mask based on logical band operations (f(x) icon). As the mask values are 1 and 0, order to set the mask on the burn_mask values == 1. Display the result and check the correctness of the mask over the true colour post fire image. Do you think the mask captures correctly the burned area?



To go further:

Visually check the correlation of the indices used in the mask building: dNBR, RdNBR, dSAVI and dNDVI. Ensure to have the index images displayed. Go to scatter plot icon () and select one index for the x-axis and other for the y-axis, then recalculate to plot the relation. Which plot has a more linear form?



6. REFERENCES

García-Llamas, P., Suárez-Seoane, S., Fernández-Guisuraga, J. M., Fernández-García, V., Fernández-Manso, A., Quintano, C., Taboada, A., Marcos, E., & Calvo, L. (2019). Evaluation and comparison of Landsat 8, Sentinel-2 and Deimos-1 remote sensing indices for assessing burn severity in Mediterranean fire-prone ecosystems. International Journal of Applied Earth Observation and Geoinformation, 80, 137-144. https://doi.org/10.1016/j.jag.2019.04.006

Miller, J. D., & Thode, A. E. (2007). Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). Remote Sensing of Environment, 109(1), 66-80. https://doi.org/10.1016/j.rse.2006.12.006