RADIOMETRIC AND SPECTRAL IMAGE ENHANCEMENT

Content

RADIOMETRIC IMAGE ENHANCEMENT

Contrast enhancement

It is important to understand that image enhancement is applied to facilitate visual interpretation and understanding of images. The enhancement will not change the radiometric values of the objects in the image; it will just allow an observer a better view of these objects. Digital images have the advantage of enabling easy manipulation of the values recorded for each pixel.

Satellite images should be improved for different reasons. Firstly, the scene brightness range may not be sufficient to cover the entire range of values supported by the sensor. If it displays no improvement, the scene will seem dark and with poor definition. Secondly, the 16-bit images of modern satellites have to be reduced to fit the 8-bit range of your computer screen.

Note: Bit-depth, i.e. colour information stored in an image, is expressed as the number of bits. The simplest 1-bit image can only show two colours (black and white). The 8-bit image can store 2^8 colours, i.e. 256, the 16-bit image can store 2^{16}, i.e. colours 65536 and that is a range of 0-65535 values.

In an unprocessed image, useful information is often included in a restricted set of numerical values among the possible values. The enhancement of the contrasts is performed by changing the initial values to use all the possible values, which increases the contrast between the targets and their environment. To understand how this type of enhancement works, one must, first, understand the concept of an image histogram. A histogram is a graphical representation of the numerical valuesof intensity that make up an image. These values appear along the x-axis of the graph. The frequency of occurrence of each of these values is presented along the y-axis.

In raw imagery, useful data often take a small portion of the available range of digital value only. The contrast of an image is a measure of its dynamic range, i.e. entire range of intensity values contained within an image (histogram spread). Contrast enhancement changes the original values, use more of the available range, increase the contrast between targets and their backgrounds, manipulate the range of digital values – its histogram (Figure 1).

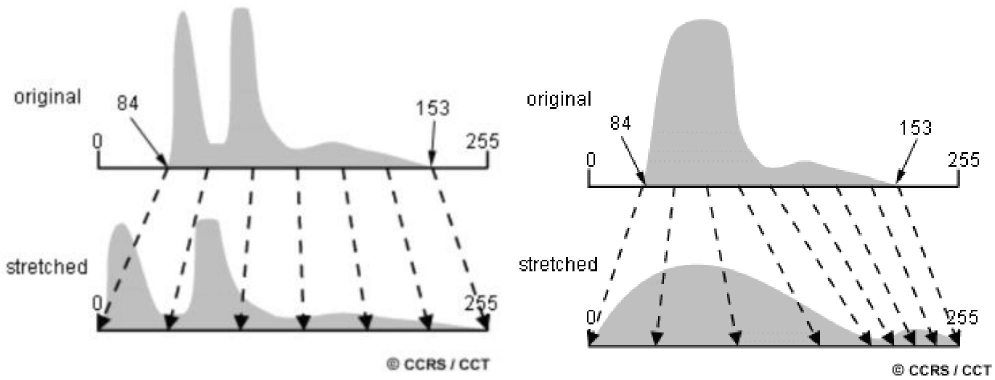

Figure 1. Histogram stretch using linear (left) and non-linear (right) functions.

In QGIS the contrast enhancement may be done in the *Symbology* tab within the *Layer properties* (Figure 2). In *No enhancements* option from the drop-down menu, input pixel values are simply rescheduled for the range of 0 to 255. In *Stretch to MinMax* option, the input is adjusted to extend between the actual input data minimum and maximum values. Although the histogram covers a larger section of the brightness range than before it. In *Stretch and clip to MinMax* option, the diagonal is adjusted so that its extremities cover 99% of the entrance. The remaining 1% of the data is set to zero for (dark pixels) or 255 (for bright pixels). The image shows a nice distribution of tones from black to white and is the best value setting of the three available options. See the difference at Figure 3.

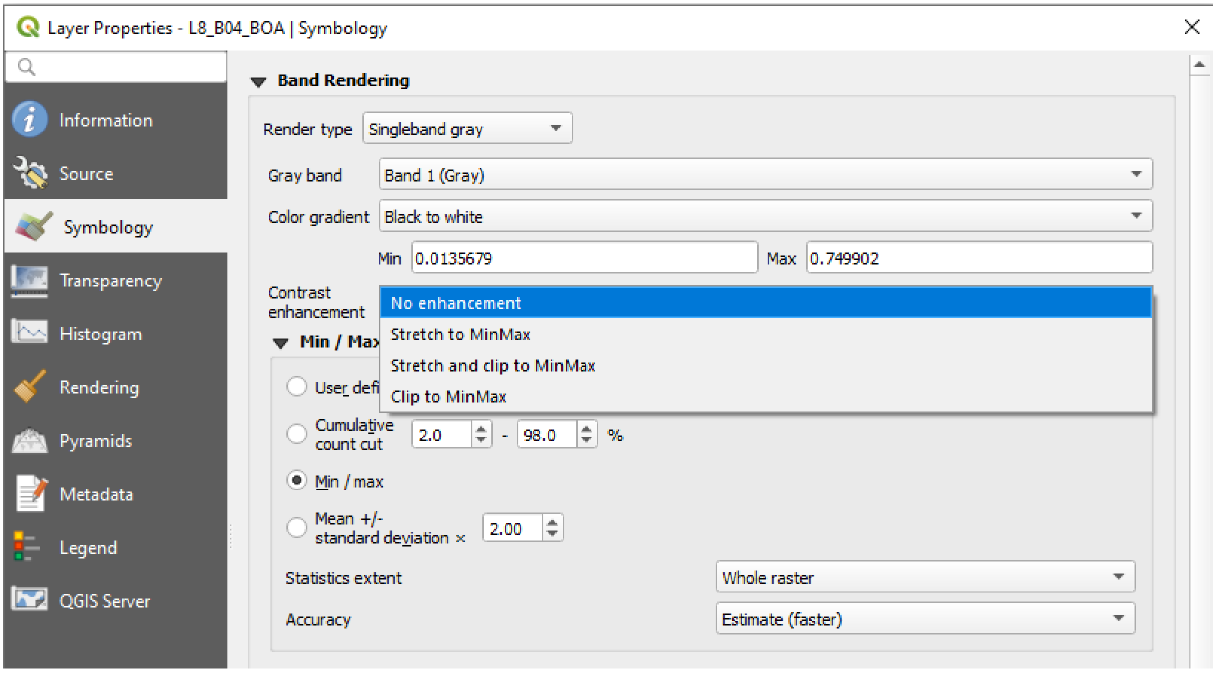

Figure 2. Contrast enhancement options.

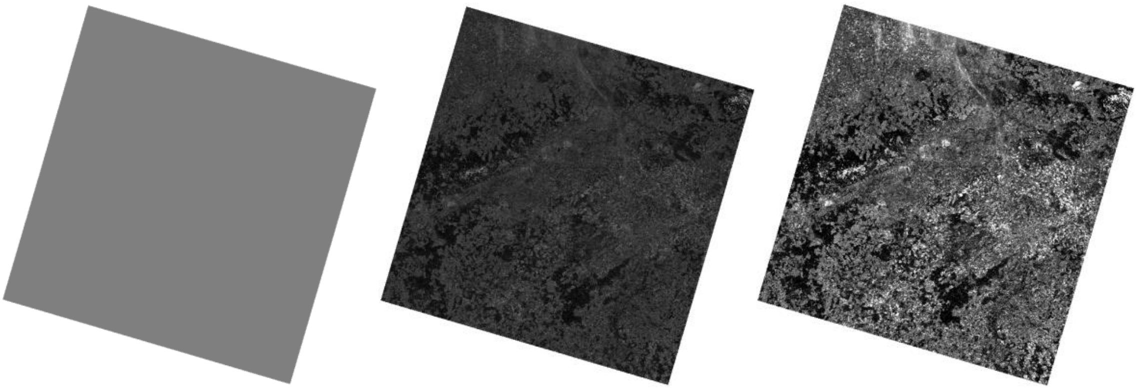

Figure 3. Contrast stretch: No Enhancement (left), Stretch and cut until MinMax Stretch until MinMax with 2% cumulative count cut (right).

Thresholding

Special cases of radiometric image enhancement are thresholding and density slices. In **thresholding**, the histogram determines the value (the threshold) that divides the histogram into two parts. Values lower than the s threshold are displayed in white (mapped phenomenon, such as water bodies) and other values are displayed in black. This produces **a binary image**. Thresholding is most often used to create masks, such as water bodies. The resulting binary image will thus represent only two values – water surfaces and other surfaces. This can be achieved, for example, by near-infrared thresholding, for which the water forms a separate peak in the histogram.

You may create a binary mask of vegetation cover using NDVI raster within the *Raster calculator* (Figure 4Figure 1).

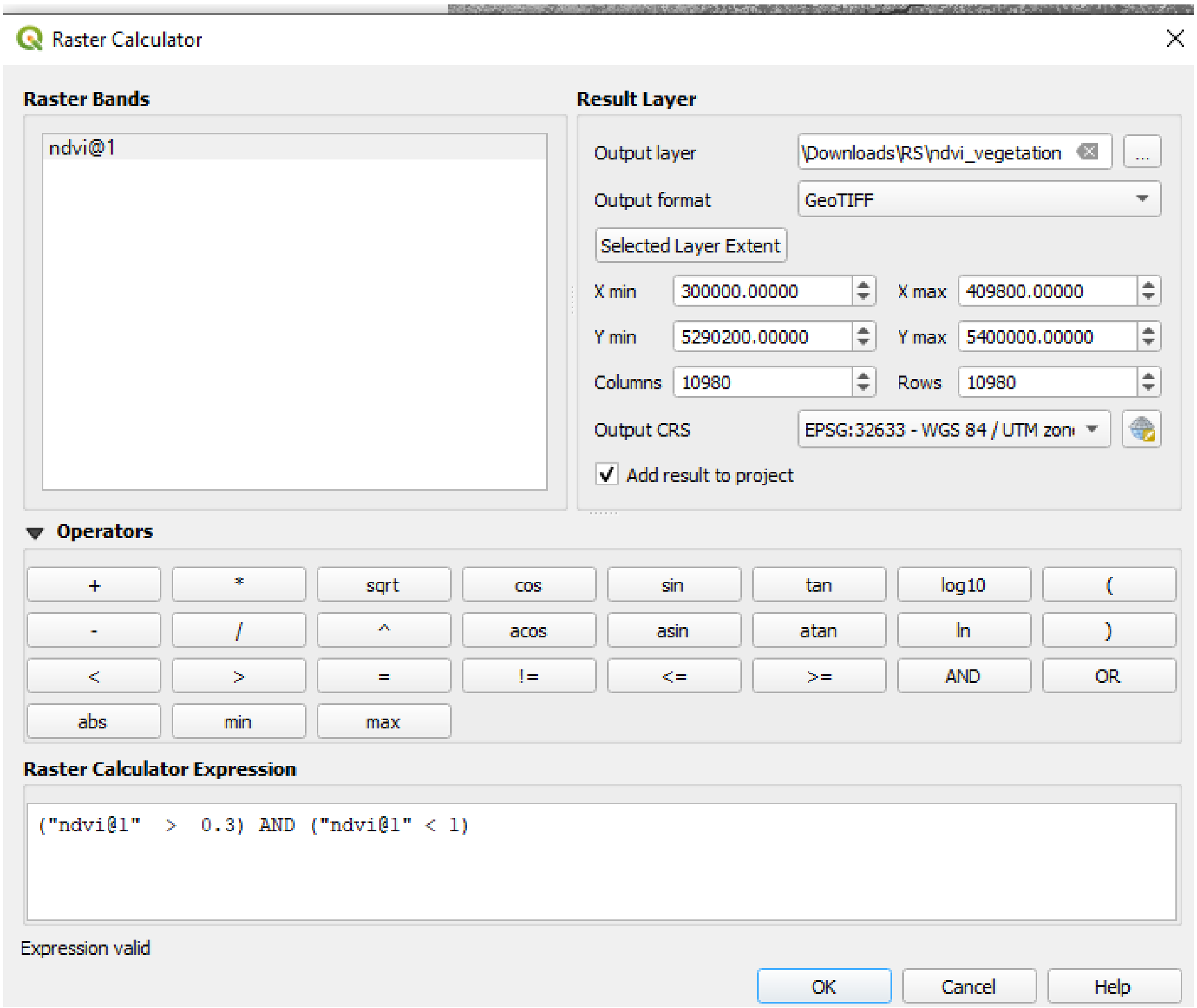

Figure 4. Thresholding of vegetation cover using Raster calculator.

You may want then to assign NoData to the specific raster values (i.e. 0 or 1). If so, use the *Translate* tool to Assign a specified NoData value to output bands (Figure 5). The resulting layer will contain only values, where the input raster was 1 (values 0 were converted to NoData).

Note: NoData values contain no information, it means that the raster will be transparent there.

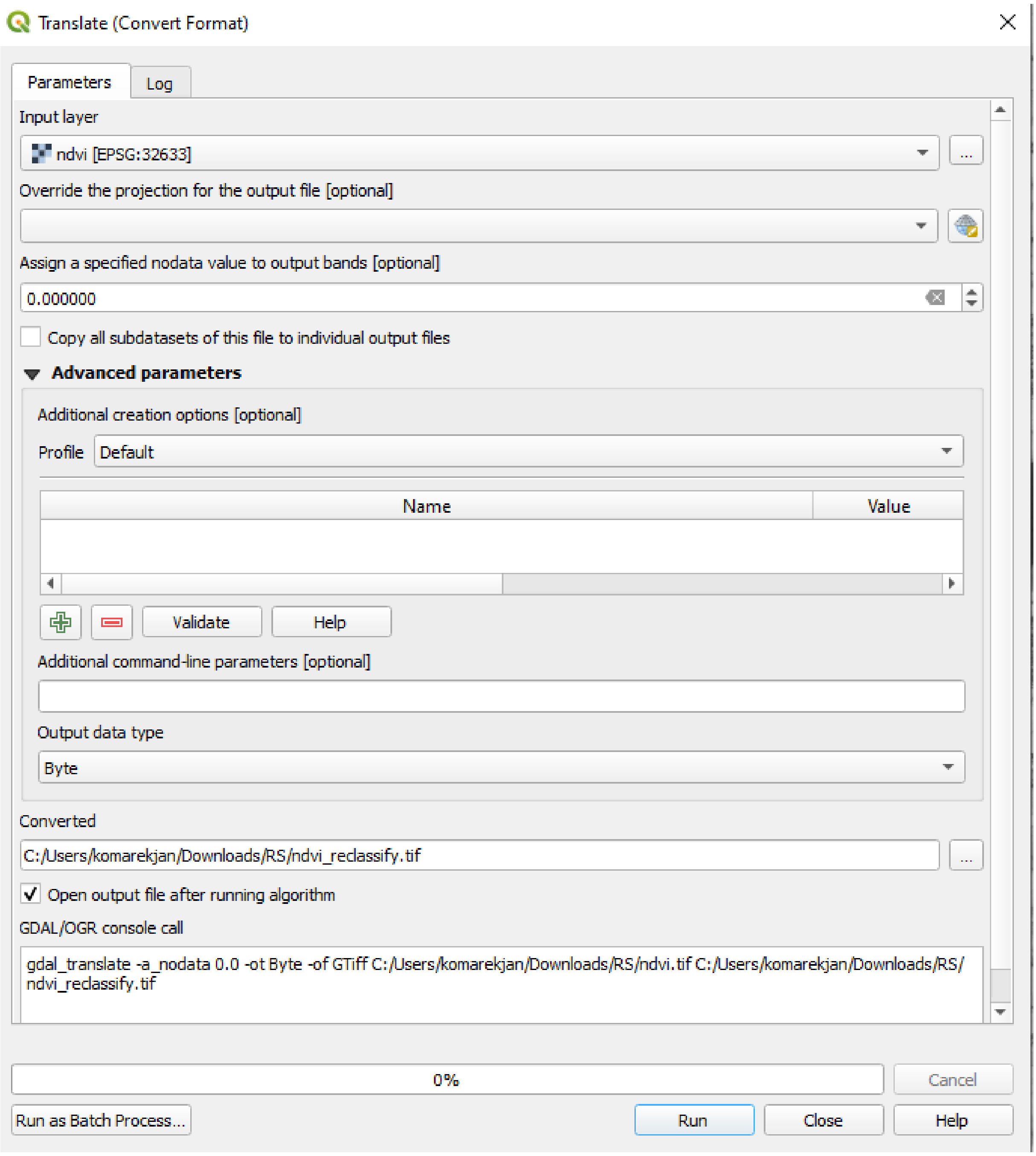

Figure 5. Assign a specified NoData value to output bands.

Another way is to use the *Raster Calculator* and times the original raster values by the binary mask. The resulting raster will only contain original values, where the mask was equal to 1.

SPECTRAL IMAGE ENHANCEMENT

Band rations

You can also enhance the image using **band ratios**. By dividing one band by another, we get an image that expresses the relative intensities of the bands, thereby enhancing the spectral diversity of the bands. Band ratios are used, for example, to highlight small differences in spectral reflectance of different types of land cover (i.e. to increase separability). The steepness of the spectral curves between two different spectral ranges will be highlighted, thus revealing minor nuances that might not be interpreted in individual images. With a multispectral sensor, tens of different combinations are possible.

A typical example is highlighting the status of vegetation and distinguishing it from other land coverings. Healthy vegetation strongly reflects in the near-infrared spectrum and absorbs in the red part of the spectrum, other surfaces (e.g. soil and water) reflect similarly in both bands. By the ratio between the two zones, we get an image where the other surfaces will have a value of around 1, while the vegetation much more. This has highlighted the state of vegetation and we can better interpret the difference between healthy and stressed vegetation or individual vegetation types Figure 6. All kinds of band ratios may be done at *Raster Calculator* functions within QGIS (Figure 7) or SCP plugin (Figure 8).

Figure 6. Sentinel-2A spectral band ratios – highlighting the differences in vegetation health status and unifying other types of landscape cover, the left image represents the red visible part of the spectrum (B4), infrared (B8) in the middle, the band ratio (B8/B4) on the right. In the red band, there is a high absorption of chlorophyll, while in the near-infrared zone there is a high reflectance of vegetation due to scattering in the lower part of the leaf.

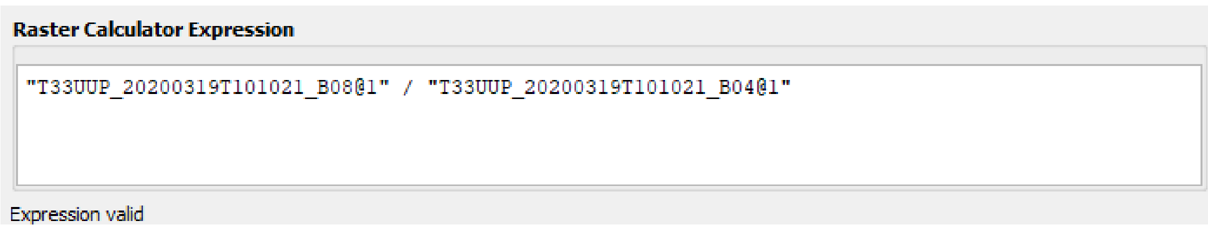

Figure 7. Simple band ratios in Raster Calculator.

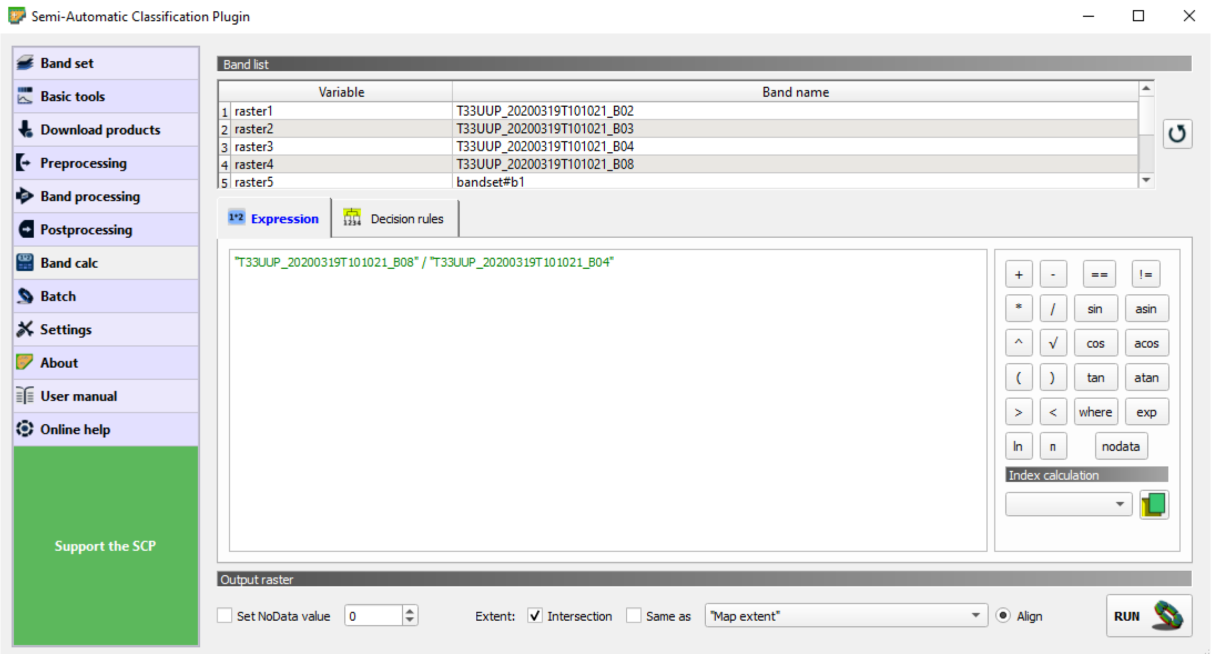

Figure 8. Simple band ratios in SCP plugin.

Spectral indices

More complex band ratios can be used to denote spectral indices, where, besides the combination of individual ratios with two or more bands, it is possible to work with various mathematical operations. These indices aim to highlight a particular phenomenon or component based on the knowledge of the spectral behaviour of objects. Frequently, spectral indices are also referred to as vegetation indices because many of them have been empirically derived to emphasize sensitivity to plant biophysical parameters or those that correlate with chlorophyll content in plants. In general, spectral indices are used to highlight areas covered by snow/water, biomass and vegetation health, differentiation of land cover classes, or soil salinity.

Spectral indices are sensitive to a specific phenomenon and are also used due to their resistance to atmospheric influences, soil colour, etc. For the calculation of spectral indices, it is suitable to use atmospherically corrected values of reflectance (Bottom-of-Atmosphere reflectance), calculating indices on uncorrected data or DN values may result in some distortion. Indices can be divided into ratios and orthogonal.

The **ratio indices** work with a simple or normalized ratio of surface reflectance in different parts of the spectrum, while **orthogonal indices** are a linear combination of the original bands. There are dozens of indexes, and for many of them, there are various variations. They have always been derived for a particular application, but given the combinations of bands used by the indices, the information often contained is very similar. In general, therefore, most indexes will be more or less correlated with each other. Below is a list of several basic ratio indices. All kinds of band ratios may be done at Raster Calculator functions within QGIS (Figure 9).

<u>Normalized Difference Vegetation Index</u>
NDVI reflects the photosynthetic activity of vegetation, positively correlates with various biophysical parameters - e.g. biomass amount, vegetation health state, chlorophyll content (Figure 10). Theoretical range of values -1 to 1.

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

<u>Soil Adjusted Vegetation Index</u>
SAVI is a variant for the NDVI index and is more sensitive to soil types, water content or saturation.

$$SAVI = \frac{(1 - L)(NIR - RED)}{(NIR + RED + L)}$$

<u>Normalized Difference Water Index</u>
NDWI is sensitive to water content in vegetation, is less affected by the atmosphere than e.g. NDVI.

$$NDWI = \frac{(NIR - SWIR)}{(NIR + SWIR)}$$

<u>Normalized Difference Build-up Index</u>
NDBI highlights built-up areas.

$$NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)}$$

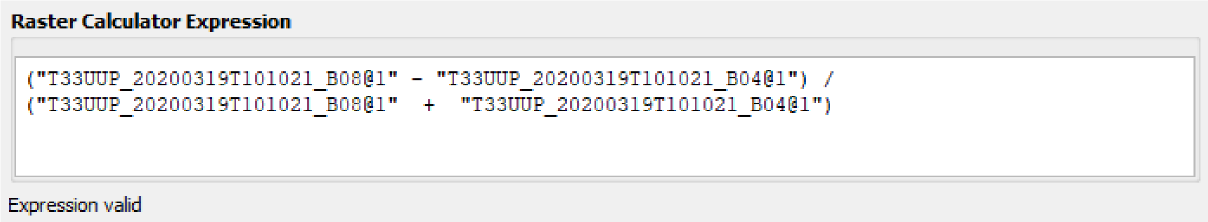

Figure 9. Calculation of NDVI ratio index on the example of Sentinel-2 image.

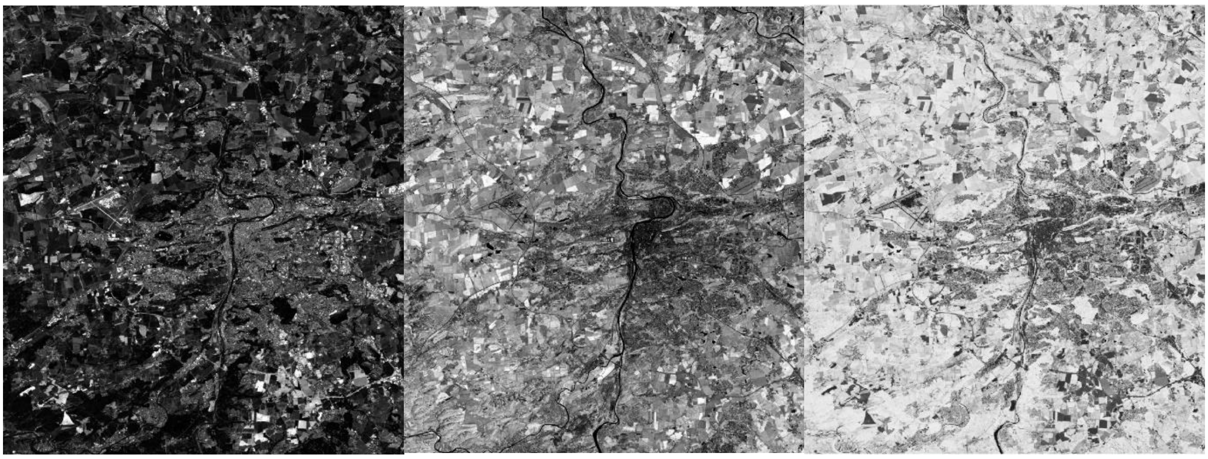

Figure 10. Proportional index of Landsat image. Red band (left), near-infrared (centre) and resulting NDVI index (right).

Orthogonal indexes transform the original bands using their linear combination. A typical representative is the *Tasseled Cap* transformation, which was designed for MSS (Landsat) sensors and is also defined for modern multispectral sensors. The result is therefore 6 new bands, of which the first three carry most of the information. This transformation gives the index of brightness, greenness and wetness. The brightness index is oriented in the direction of the highest variance of the soil reflectance values, so it is de facto the reflectance of the soil (high values indicate bare soil, low vegetation and water bodies). The greenness index (vegetation index) is perpendicular to the brightness index and is oriented in the direction of the highest contrast between the visible and infrared part of the spectrum. The index is thus an indicator of green matter (high values indicate a high amount of green). Wetness index correlates with the two previous ones and indicates de-facto water content (the highest values indicate water areas, low then bare soil and greenery).

Try to search for possible spectral indices, there are many of them. You can visit for example https://www.indexdatabase.de.