

Workflow with the eBee Ag:

With the choice of purchasing the new eBee Ag, you may also choose between a variety of different camera types that are offered along with the eBee Ag. To help you with this decision, this document will explain you the basics of multispectral imaging, the differences between the "S110 RGB", "S110 NIR", "S110 RE" and "multiSPEC 4C" cameras as it will also outline the new options in eMotion and Postflight Terra 3D software.

Camera information and multispectral imagery basics

What we usually call "light" is in fact just the (for humans) visible part of the electromagnetic spectrum. This part ranges from wavelengths of about 400 nm (purple) to approximately 700 nm (red). This is also the range of reflected radiation that standard "RGB cameras" capture.

Below and above the visible part of the electromagnetic spectrum, you find ultraviolet and infrared radiation, respectively. We cannot see those wavelengths, but the characteristic reflectance of different surfaces like plants or soil in some of those parts of the electromagnetic spectrum (especially the near-infrared) are used to conduct a variety of analyses like vegetation indices, plant stress or similar (JOSEPH, G. 2005, p. 2, 4, 26, 27).

In order to capture the reflected radiation in a certain wavelength range, a camera needs a specific sensor. The locations and the band widths in the electromagnetic spectrum that a sensor is able to capture are what we call *spectral bands*. Many consumer cameras have been developed for three different spectral bands. Such is the case of the "RGB camera", which acquires bands of red (630 - 700 nm), green (490 - 560 nm) and blue (450 - 490 nm) color (JOSEPH, G. 2005, p. 7, 8 and LUKAC, R. 2012, p. 3, 4). Standard three band cameras have been adapted to obtain different bands of information. This is accomplished by shifting desired bands into either the red, green or blue channel. The "S110 RE" and "S110 NIR" are examples of this.

The "S110 NIR" consists of the red (570 - 690 nm), green (510 - 660 nm) and NIR (780 - 1000 nm) bands and is therefore able to capture the amount of near-infrared radiation a surface reflects. This is especially useful to calculate indices like the normalized difference vegetation index (NDVI) (JOSEPH, G. 2005, p. 74).

The "S110 RE" captures a blue, green and red edge band, the latter corresponding to wavelengths of 670 - 760 nm. With this camera, certain other methods like plant stress or senescence analysis can be calculated. The individual bands in cameras like the RGB, RE or NIR overlap (see figure 1) to produce a more balanced image, but each overlapping channel can cause small amounts of noise in other bands. As a result, this noise can lead to an imperfect readout.

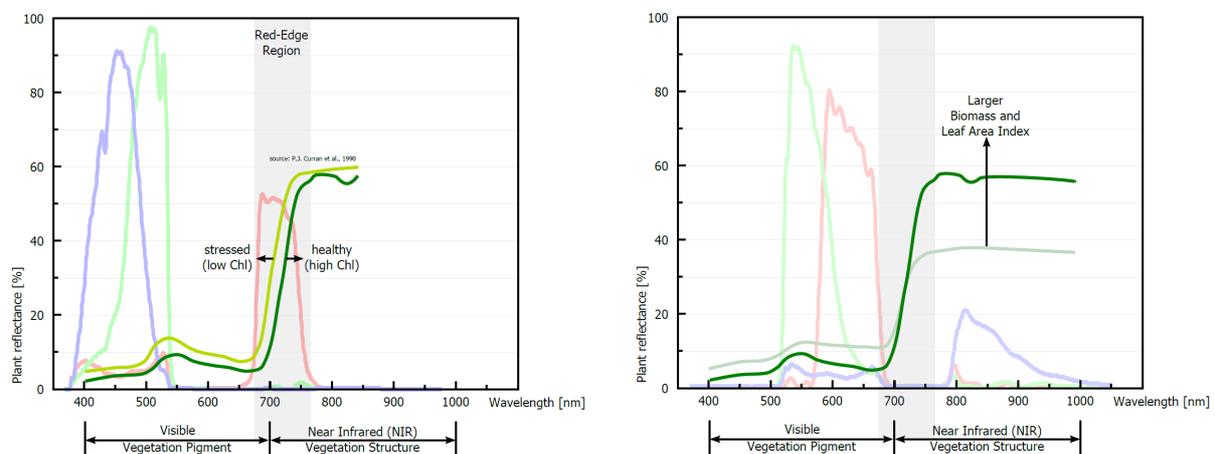


Figure 1: Reflectance of plants in different wavelengths as captured by the "S110 RE" (left) and the "S110 NIR" (right)

Band arithmetics are carried out by eMotion to reduce such overlaps, which results in the band-widths shown in the graphs. However, it is not possible to eliminate these overlaps completely. Therefore, we offer a fourth camera, the "multiSPEC 4C". With this camera, each band corresponds to an enclosed part of the spectrum that does not overlap with other bands (see figure 2).

The explanations above become clearer when having a look at below-mentioned figure.

On the x-axis you find the electromagnetic spectrum given in wavelength. The visible part of the spectrum is indicated from 400 to 700 nm while the near-infrared part ranges from 700 to 1000 nm in this case. On the y-axis you find the amount of reflectance by plants in percentage.

The four pale spikes represent the band widths of the "multiSPEC 4C" while the bright green/light blue and dark green graphs resemble stressed and healthy vegetation, respectively.

As you can see, the plant reflectance rises suddenly at about 700 nm. This is the border region between red and infrared radiation and is therefore called *red edge*. Due to this sudden increase in reflectance by plants, this region of the electromagnetic spectrum is of utmost importance for agricultural questions.

High chlorophyll contents tend to shift the reflectance curve to larger wavelengths, indicating healthier vegetation (VOGELMANN 1993, p. 4). The light green and light blue graphs, both representing stressed vegetation, differ in terms of biomass amount and leaf areas. Higher reflectance values usually refer either to healthier vegetation or more biomass/larger leaf areas (JOSEPH, G. 2005, p. 66, 67, 68).

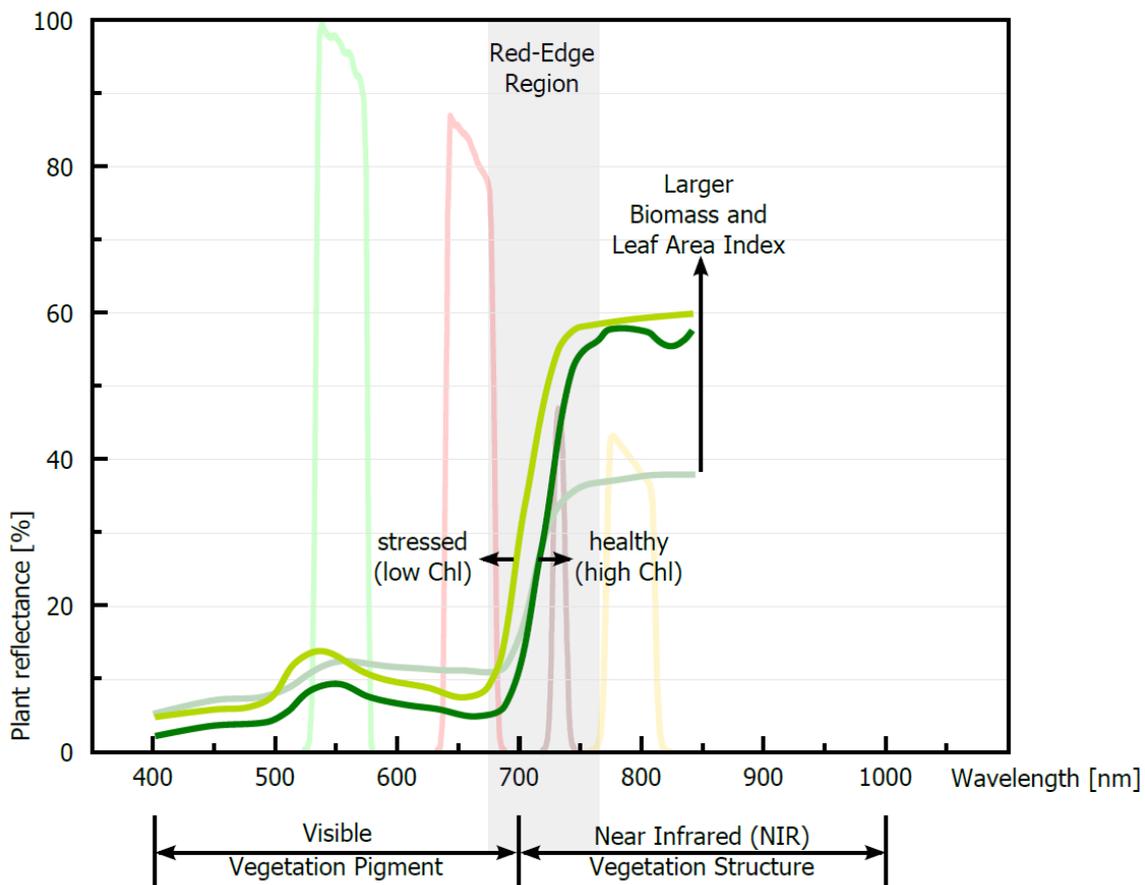


Figure 2: Spectral bands of the "multiSPEC 4C" (pale spikes). Characteristical reflectance of healthy (dark green) and stressed (light green/light blue) vegetation

RAW images and eMotion flight data management

The optional "S110 RE", "S110 RGB" and "multiSPEC 4C" cameras that can be purchased in combination with the eBee Ag save captured photos in RAW format additionally to JPEG. In order to provide accurate index calculations, the camera must be set to grab RAW images instead of JPEG.

RAW means that the image is basically in the original state as caught by the cameras sensor. JPEG images are processed right within the camera, based on your camera settings as well as camera model dependent preferences. That is, for example, adding contrast, brightness, noise reduction, sharpening and others. Afterwards, it is compressed into JPEG format, which is optimal for visualization. JPEG is a 'loss' file format, meaning that some of the information that has been available in the RAW format will be ultimately lost after the compression. For example, RAW format allows brightness gradation of up to 16 bits, while JPEG files are only capable of 8 bits brightness information. Summarizing, RAW files are larger, look dark, flat and lack contrast but contain more information and are intended for professional post-processing.

JPEG is sufficient for most use-cases in standard aerial imagery, but it is not suitable for index calculations like NDVI and others. For those purposes, TIFF files are beneficial since they will not lose the information stored in the RAW files. Therefore, eMotion now allows for the usage of RAW images and conversion to TIFF files.

When opening the flight data manager following your flight, you will be asked in the "prepare data for import" section if you want to import RAW files. If you wish to do so, you have to select the type of your camera first (see figure 3). Afterwards, you will have to select the flight log as usual. The RAW images will then be imported and converted to TIFF files (see figure 4), which you can open and process with Postflight Terra 3D.

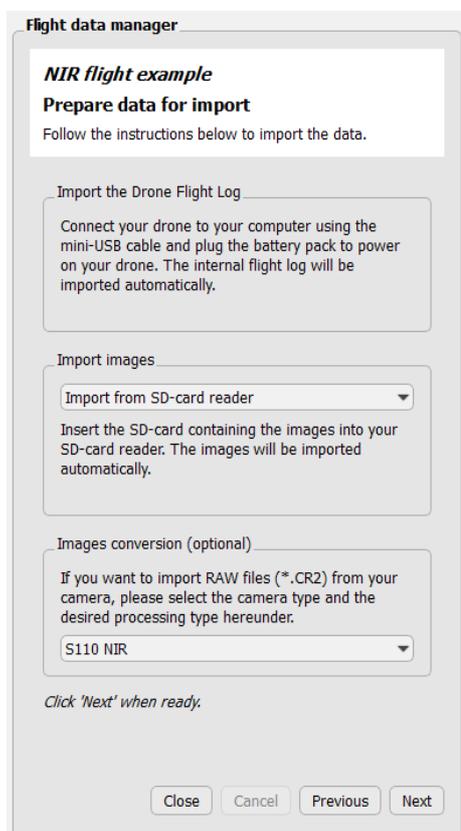


Figure 3: Optional image conversion of RAW images

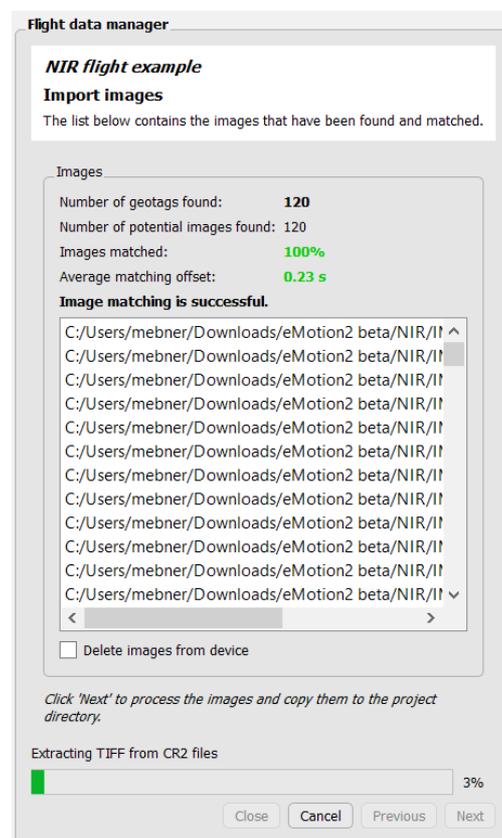


Figure 4: Extraction of TIFF files from RAW images

Index calculations and false-color maps

The latest version of Postflight Terra 3D complements the eBee Ag and eMotion in terms of index calculations and RAW file support.

Index calculator:

In the toolbar of Postflight Terra 3D you will find a new icon, the index calculator . If you click on it, a sidebar on the right hand side of the window will appear. Here, you will find three sections:

(1) Reflectance Map, (2) Index Mosaic and (3) Colored Index Mosaic.

(1) You have to generate a reflectance map (figure 10) with band statistics prior to index calculation (figure 5). You can specify the output resolution of the map, but if you do not change this value, the average GSD of your project will be used. After generating the reflectance map, you will find different statistical values for each separate band available. Those are minimum, average and maximum reflectance as well as standard deviation and variance (figure 6).

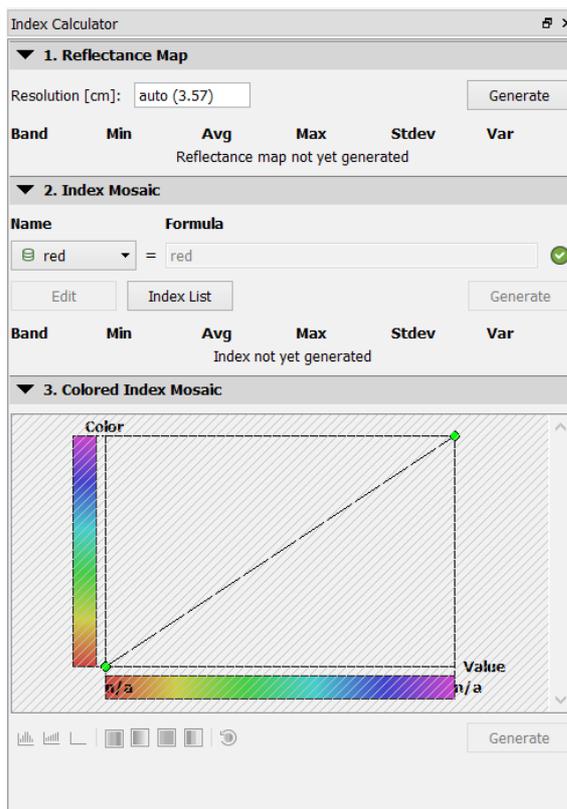


Figure 5: Index calculator sidebar prior to generating the reflectance map

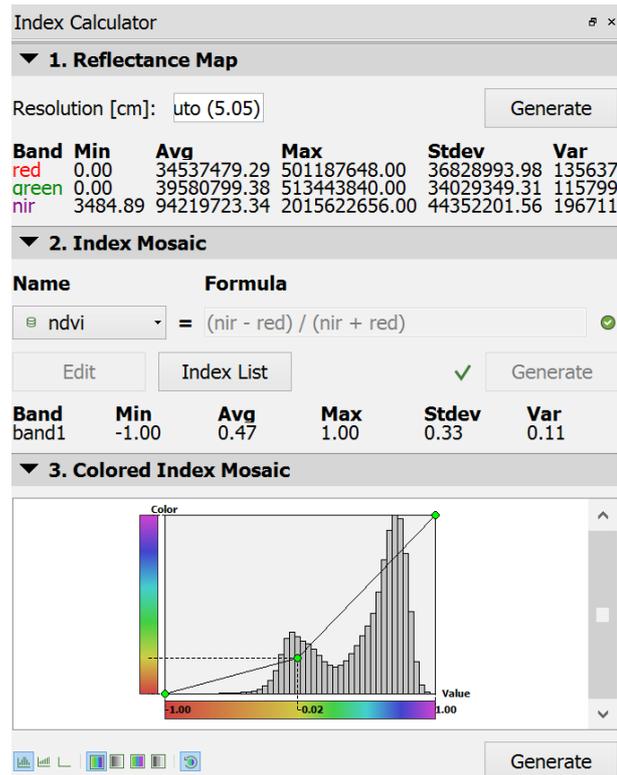


Figure 6: Index calculator sidebar after reflectance map has been generated. Various statistics are available for each band

(2) In the Index Mosaic section (figures 5 and 6) you have the option to generate new mosaics based on desired calculations. Predefined calculations are the single bands (if you want to display a mosaic in only one band), grayscale and NDVI.

You can also easily add your own indices/formulas by clicking on >>Index List >>Add. Here, you can select single bands and add them to individual mathematical formulas (figure 7). You can also set a name for your formula.

After selecting the desired calculation, click on *generate* to compute the new mosaic.

You can generate different mosaics without losing previously generated ones as they are automatically saved in an extra folder under the name of the index when being generated (e.g. if you generate an NDVI, the mosaic will be saved in 'workspace/4_index/indices/ndvi').

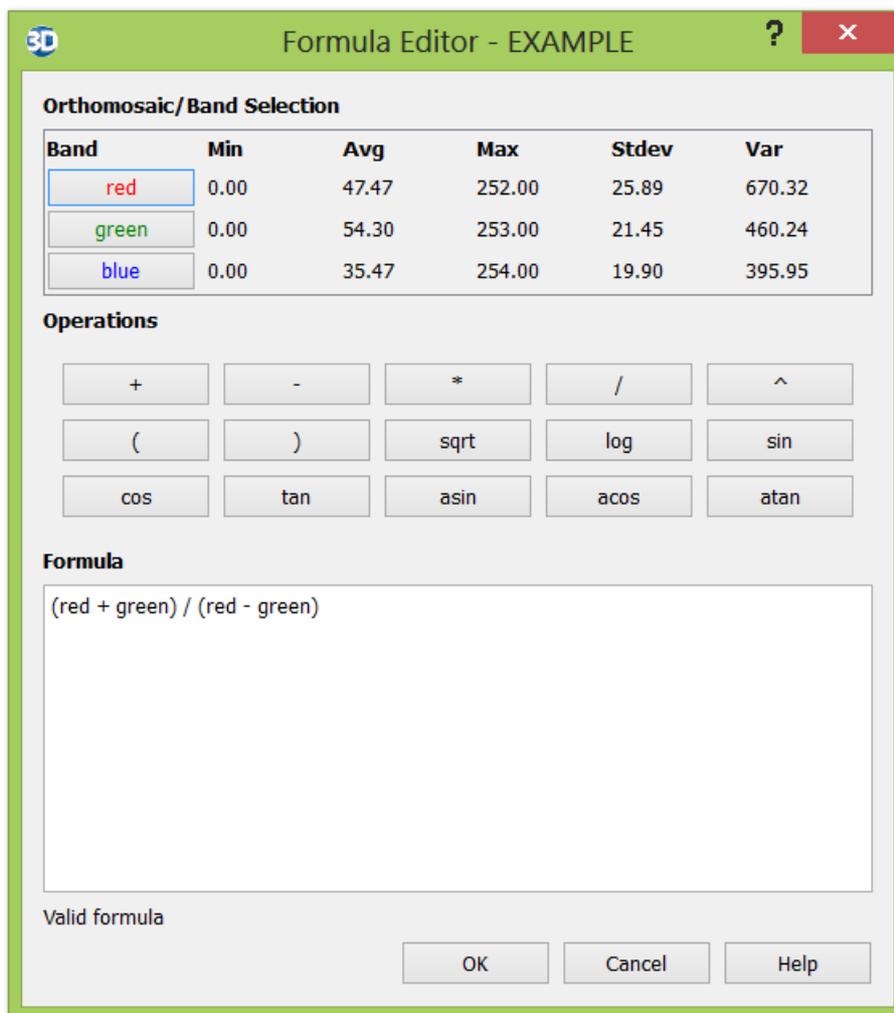


Figure 7: Creating custom indices

(3) The colored index mosaic section (figures 5 and 6) lets you color the index mosaic created in the previous step (the option becomes available after generating an index). You can display histograms of the color value distribution and switch the display from 'normal histogram' to 'cumulative histogram' or 'no histogram' (figure 8) by clicking the corresponding icon .

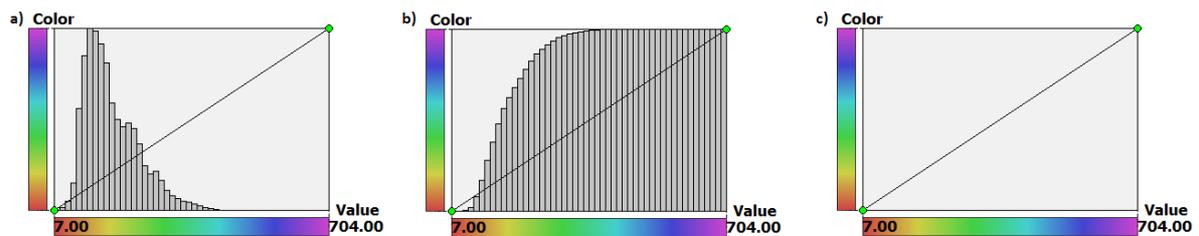


Figure 8: Color value distribution as a) normal histogram, b) cumulated histogram or c) no histogram

By hovering the cursor over a certain histogram class, its class-width and amount of values in percentage will be displayed (figure 9).

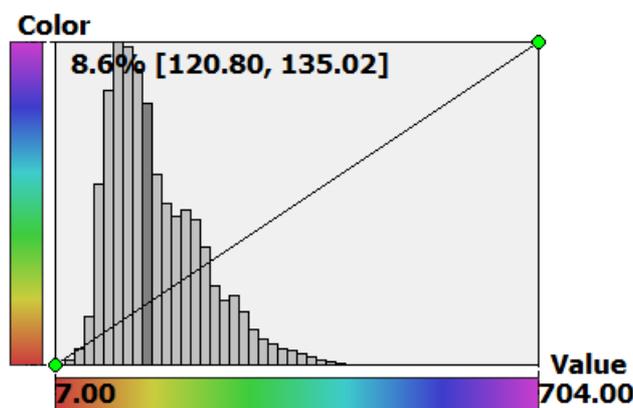


Figure 9: Amount of values in percentage and class-width are displayed when hovering over a class

Furthermore, it is possible to adjust the color display of the mosaic directly and save it. You have the choice between four modes, 'color gradient', 'gray gradient', 'color classes' or 'gray classes'. You can reset your changes by clicking on the circular arrow .

It is possible to move the gradient line by clicking on one of the green anchors and dragging it. This way, you can highlight or exclude certain colors. If you want to group values in classes, simply right-click on the line, add anchors, select 'color classes' and adjust the classes as you wish (figures 10 and 11).

When satisfied with the result, click on *generate* and the mosaic will be saved in the 'index' folder you are working on in your workspace (i.e. if you compute an NDVI in step (2), adjust the colors in step (3) and generate the 'colored index mosaic', it will be saved in the NDVI folder in '4_index/indices' in your workspace). Note that if you generate a new colored index mosaic, the previous one will be overwritten.

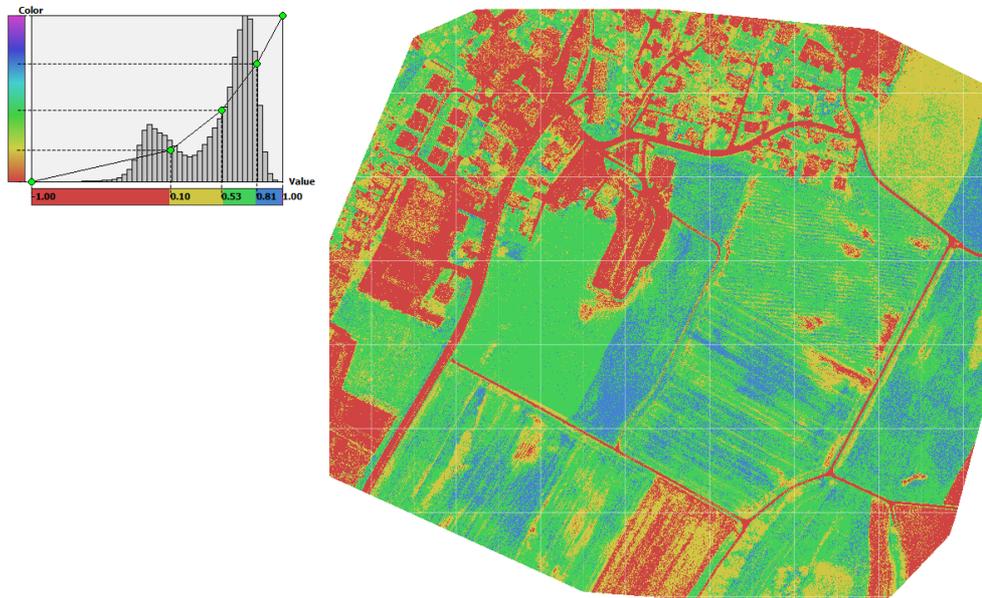


Figure 10: Classifying values in the reflectance map. Here, a NDVI index mosaic has been divided into four classes. The red class, corresponding to NDVI values from -1 to 0.1 represent streets, buildings or bare soil. The yellow class, from 0.1 to approximately 0.5 shows shrubs and grass. Values from 0.5 to 0.8 show dense vegetation and crops. All values above represent forest or crops in their peak growth stage

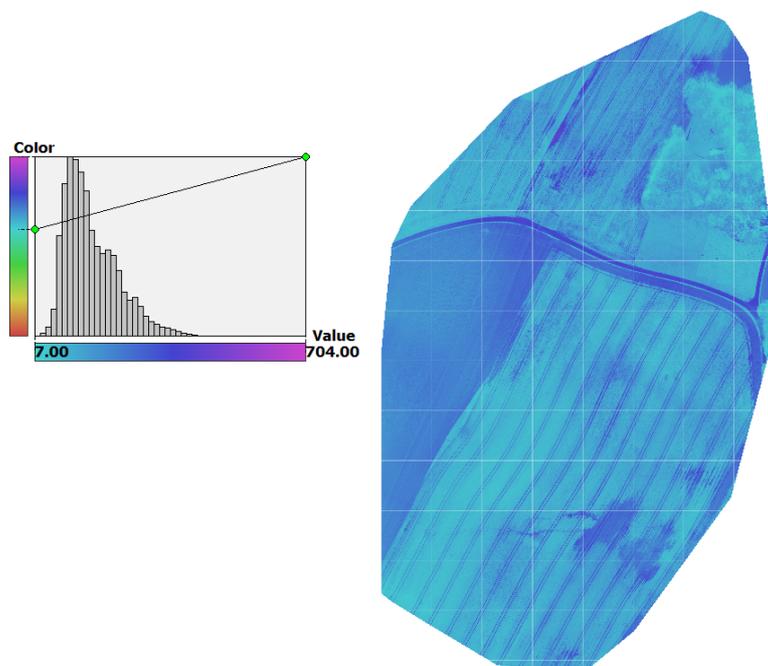


Figure 11: Adjusting the color gradient line

Bibliography

JOSEPH, G. (2005): Fundamentals of Remote Sensing. Universities Press. 486 pages.

LUKAC, R. (2012): Single-Sensor Imaging: Methods and Applications for Digital Cameras. CRC Press. 600 pages.

VOGELMANN, J.E., ROCK, B.N. & MOSS, D.M. (1993): Red edge spectral measurements from sugar maple leaves. In: International Journal of Remote Sensing, 14, 1563 – 1575.

List of abbreviations

CHL = chlorophyll

GSD = ground sampling distance

NDVI = normalized difference vegetation index

NIR = near infrared

NM = nanometer

RE = red edge

RGB = red, green, blue