Introduction

In this tutorial, we are going to use QGIS software and an aerial image (taken with an AREN MonoCam Aeropod) to produce a new image that highlights the amount of the image that is likely to be green vegetation. To do so, the software will need to analyze the values in each *pixel* in the image and perform a calculation that converts them to new values. The calculation, or *algorithm,* uses what is called a measure of "Green-ness", and works off the assumption that in an aerial image, greener things tend to be healthy vegetation.

The algorithm is called the Green Leaf Index, or Visual-Light Difference Vegetation Index (GLI/VDVI). This index assigns a value to each pixel in the image. The values will fall within a range of -1.0 to 1.0, with -1.0 being *highly unlikely* to be vegetation, and 1.0 being *highly likely* to be vegetation. 0.0 is the middle value, with positive and negative values being more and less likely to be vegetation, respectively. The output will be an image that represents this index with a color ramp (Image 2). We will also produce a *dichotomous* image – one that divides the pixels into just two classes - likely vegetation and unlikely vegetation (Image 3).

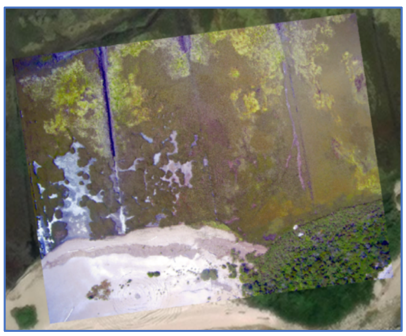


Image 1 – Aerial Image

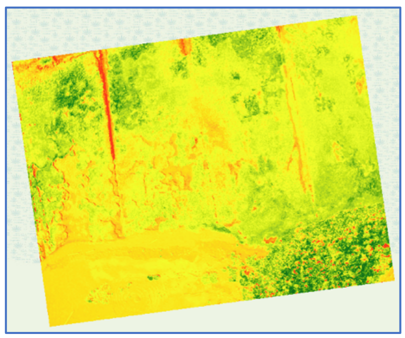


Image 2 – GLI-VDVI Image

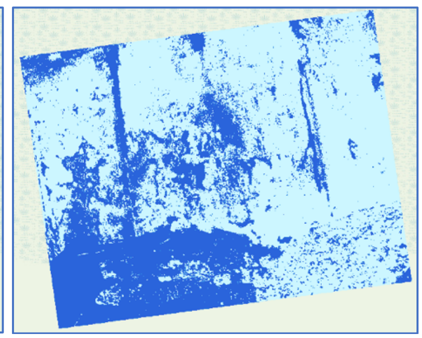


Image 3 – GLI-VDVI – Dichotomous

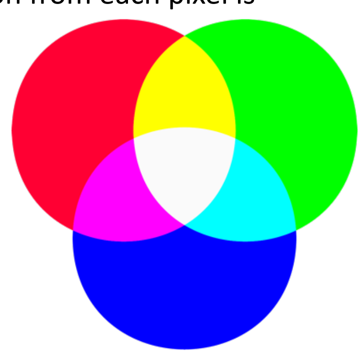
Background: What's in a digital image?

Digital cameras record images on a sensor, which is made up of millions of tiny cells, called *pixels*. The pixels are arranged in a grid (or *array*). A pixel is the smallest unit in the image, and along with the camera lens, determines the level of detail, or *spatial resolution*, of the image.

When we view digital images on a computer screen, the information from each pixel is displayed on a corresponding pixel on the computer screen. This is done by transferring the information about each pixel's color and brightness (or *luminance*) to the computer and then mixing the light emitted from the pixel on the computer to match.

Each pixel in a digital image is composed of three channels: a Red channel, a Green channel, and a Blue channel.

When mixing light, the primary colors are red, green, and blue. Combining the primary colors of light to produce other colors is called the *additive color model*.



Graphic 1 – Additive Color Model

An equal mixture of all three primary colors at 100 % luminance produces white. All other colors can be produced by mixing the primary colors with varying levels of luminance.

Each of the three channels in a pixel contains a numeric value equal to the brightness or luminance of that channel in that pixel. In an 8-bit image, the values for each channel range from 0 - 255, with 0 representing no luminance and 255 representing 100% luminance.

If all three channel values in a pixel are at full luminance (R = 255, G = 255, B = 255), the pixel will appear white. If all three channel values are at no luminance (R = 0, G = 0, B = 0), the pixel will appear black. A pixel with a value of 255 in the red channel, 0 in the green channel, and 0 in the blue channel (R=255, G=0, B=0) will appear Red.

Color	Pixel Values	Color	Pixel Values	Color	Pixel Values
	R = 255 G = 255 B = 255		R = 0 G = 0 B = 0		R = 255 G = 0 B = 0

Table 1 – Pixel Values for White, Black, and Red

Below, the zoomed-in detail image on the right displays the pixels in the area around the Heron's eye as seen on a computer screen. In a digital image, such as this one, the values in the three channels combine to determine the output color and brightness of each pixel.

Image 4 – Digital Image (Great Blue Heron)

Image 5 –Image Detail (Pixels)

Next, we see images of the individual red, green, and blue channels without the channel color applied. Here, a value of 0 in a pixel is represented by black, and a value of 255 is represented by white. All other values are shades of gray. Notice how the vegetation values are lighter in the green channel, indicating more reflectance than the red or blue channels. What other differences do you see?

Image 6 – Red Channel (grayscale)

Image 7 – Green Channel (grayscale)

Image 8 – Blue Channel (grayscale)

When we represent each channel with its color, it looks similar to what we see below.

Image 9 – Red Channel (color)

Image 10 – Green Channel (color)

Image 11 – Blue Channel (color)

Color Mixing

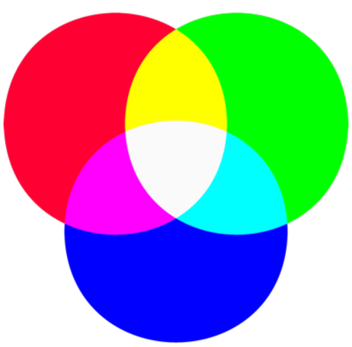
If we combine just two of the three channels, different features start to appear. Below, from left to right, we see images showing the red + green, red + blue, and green + blue channel combinations.

Notice how the colors in each image fall into the range of the combination values in the Additive Color Model (Graphic 2). (The R+G image is largely in the yellow range, the R+B image is mostly magenta, and the G+B image is mostly cyan.)

Image 12 – Red + Green (RG)

Image 13 – Red + Blue (RB)

Image 14 – Green + Blue (GB)



Graphic 2 – Additive Color Model

When we combine all three channels, we see what appears to us as a natural color image.

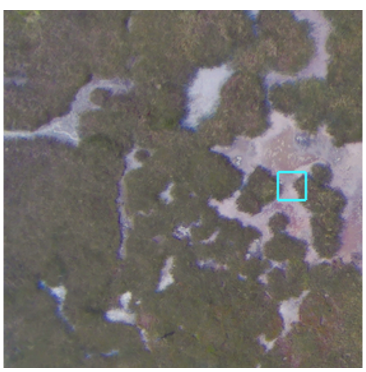
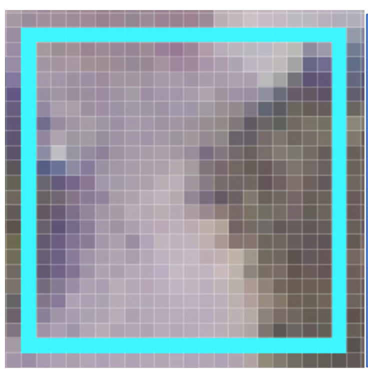
Image 15 – Full Color (RGB)

In a digital image, each pixel has a value in each of its three channels that blend to produce an exact color. Following is a table with some examples of pixel colors with their corresponding Red, Green, and Blue channel luminance values:

Color	Pixel Values	Color	Pixel Values	Color	Pixel Values	Color	Pixel Values
	R = 255 G = 255 B = 255		R = 125 G = 125 B = 125		R = 83 G = 129 B = 53		R = 226 G = 239 B = 217
	R = 0 G = 0 B = 0		R = 255 G = 255 B = 0		R = 156 G = 194 B = 229		R = 197 G = 224 B = 179
	R = 255 G = 0 B = 0		R = 255 G = 0 B = 255		R = 255 G = 217 B = 102		R = 168 G = 208 B = 141
	R = 0 G = 0 B = 255		R = 255 G = 125 B = 0		R = 247 G = 202 B = 172		R = 83 G = 129 B = 53
	R = 0 G = 255 B = 0		R = 255 G = 125 B = 0		R = 196 G = 89 B = 17		R = 56 G = 86 B = 35

Table 2 – Pixel Values for a Selection of Colors

In the example images below, the small rectangle in the image on the left is enlarged in the image on the right so that we can see the individual pixels (they appear as small squares of color). The table to the right of these images reveals the actual rows and columns of color channel values the computer uses to color each pixel. The channels are listed on the left: (1 = red, 2 = green, 3 = blue). Each row and column is numbered and corresponds to the position of the pixel in the image. (This is just a small section of the table.)

11			775	776	777	778	779	780	781	782	783
659	1	144	133	137	143	145	149	145	143	150	158
	2	125	114	114	120	132	135	128	124	126	136
	3	153	144	140	149	150	152	147	143	150	159
660	1	130	138	147	140	143	149	145	143	155	154
	2	114	118	130	122	123	132	126	126	134	135
	3	141	143	149	146	148	151	146	145	153	155
661	1	137	154	131	129	148	149	141	144	147	155
	2	123	140	118	116	129	132	123	130	129	132
	3	146	153	138	142	151	151	145	145	145	152
662	1	134	144	130	142	141	147	156	148	145	158
	2	119	123	114	131	124	128	139	126	121	133
	3	142	142	140	148	143	150	157	147	145	155
663	1	154	141	136	142	139	146	152	151	152	154
	2	141	122	111	120	120	127	134	132	130	131
	3	159	141	133	141	140	149	156	151	151	151
664	1	151	138	153	141	138	137	155	152	147	156
	2	139	114	132	124	115	117	134	131	130	134
	3	153	136	149	142	141	144	153	150	146	147

Image 16 – Digital Image with Pixel Detail and Luminance Values Table

Because digital images are actually tables of numerical pixel channel values, we can explore those values and use algebraic formulas (algorithms) to identify and enhance certain features. This enables us to learn more from the data in an image than is apparent just to our eyes.

In this tutorial, we are going to use an algorithm called the Green Leaf Index (GLI) or Visible-Band Difference Vegetation Index (VDVI) to create an index of 'Green-ness," which is a reasonable proxy for healthy vegetation. (The greener something appears, the more likely it is to be healthy vegetation.) The caveat of this method is that some other materials, such as artificial turf, may also appear green and show up as vegetation. This is where aerial interpretation skills, along with ground-truthing, can help to clarify results.

The formula for the Green Leaf Index GLI/ VDVI is:

(2 x Green - Red - Blue) / (2 x Green + Red + Blue)

where Red, Green, and Blue are the corresponding pixel values in the red, green, and blue channels of the image.

In the following exercise, we will apply this formula to a *georeferenced* image in ArcGIS Pro. (Georeferencing is the process of adding coordinate information to an image so that it can be mapped to the surface of the earth.) We will then modify the style (or *symbology*) of the resulting image to better see our results. You can produce your own georeferenced image using the AREN Georeferencing with ArcGIS Pro tutorial.

Creating the Green Leaf Index/Visible-light Difference Vegetation Index

Part one: Open a new project in ArcGIS Pro and import a raster using the Raster Calculator

1. Launch ArcGIS Pro and open a new Map project. (If it is already running, open a new Map project.)

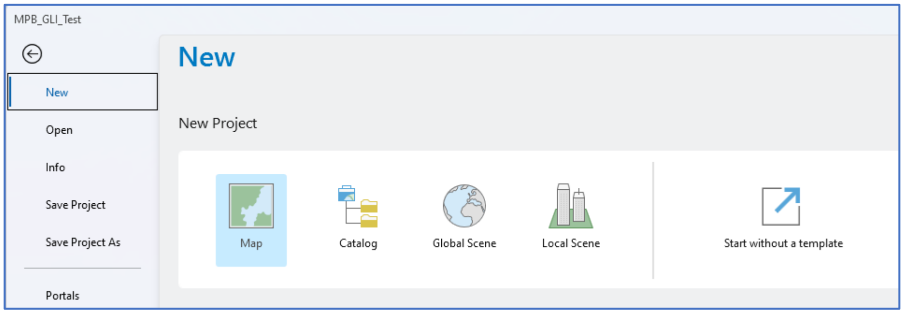


Figure 1 – Launch a new Map Project

2. Name your project and select the project location, then click OK

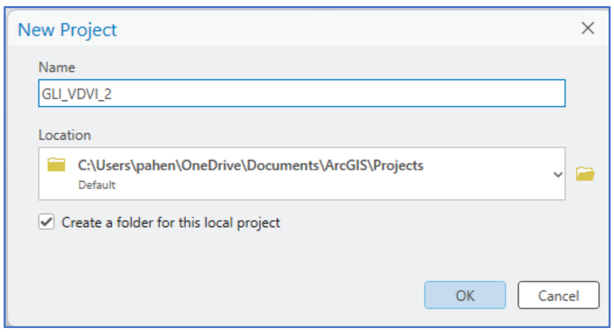


Figure 2 – Name Project and Save Project Location

A new project window appears.

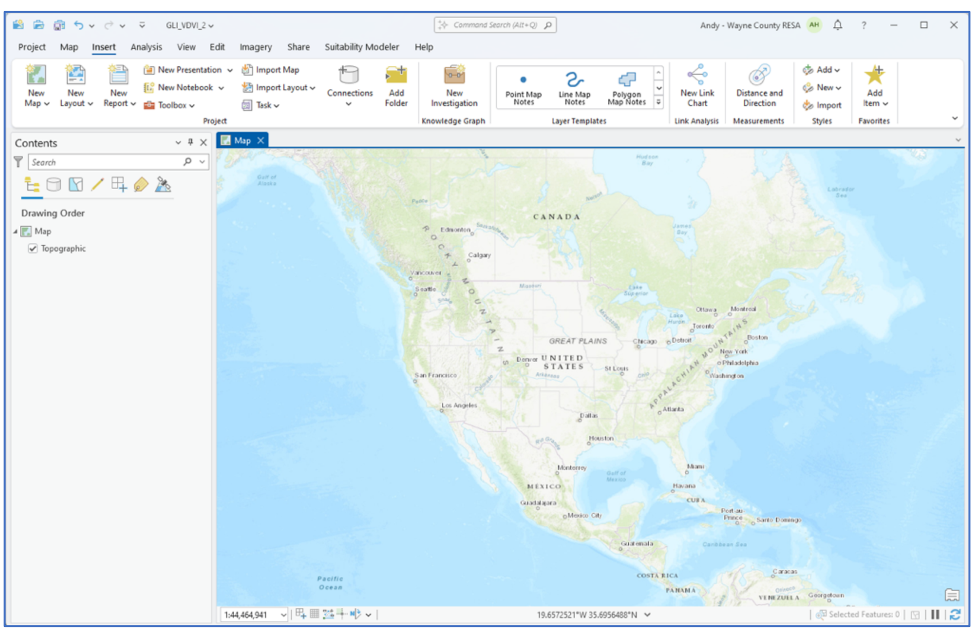


Figure 3 – New Map Project Window

3. Click on the Analysis Tab, then click on Tools to open the Geoprocessing tools panel

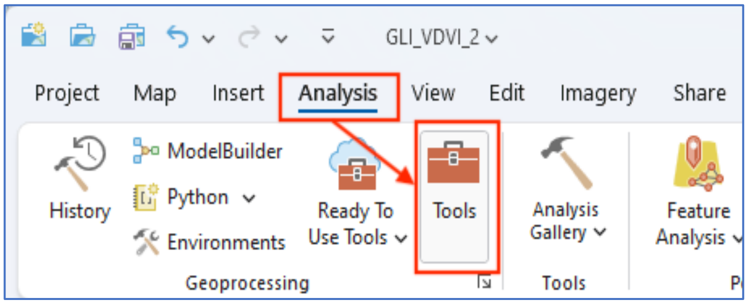


Figure 4 – Open the Geoprocessing Toolbox

The Geoprocessing tools panel will open. We will use the Raster Calculator tool to import your image as a three-band raster file.

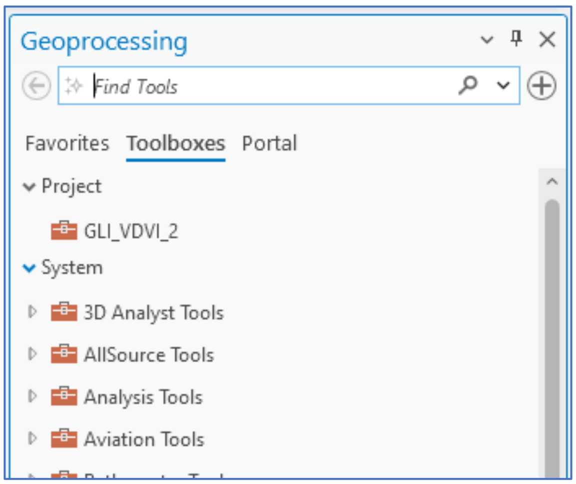


Figure 5 – The Geoprocessing Toolbox Panel

4. Type "Raster Calculator" into the Search Bar

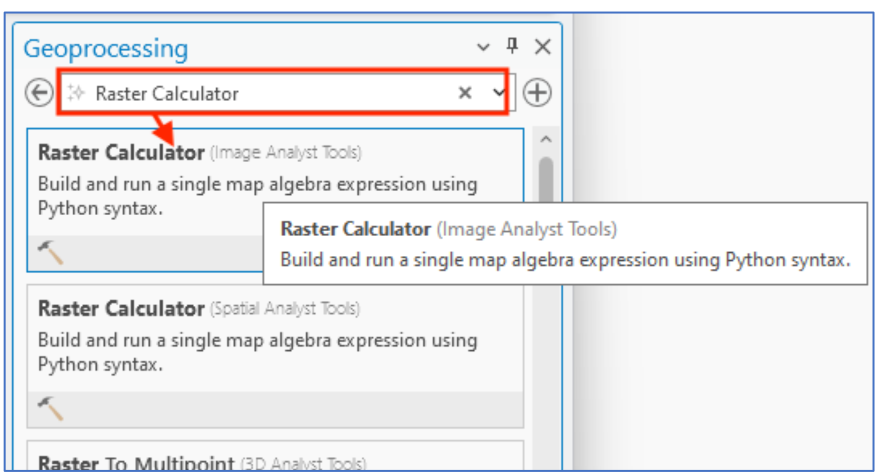


Figure 6 – Search for the Raster Calculator tool

5. Click on the first Raster Calculator option (Image Analyst Tools) to open the Raster Calculator.

6. When the Raster Calculator window opens, click the **Add Rasters** Icon

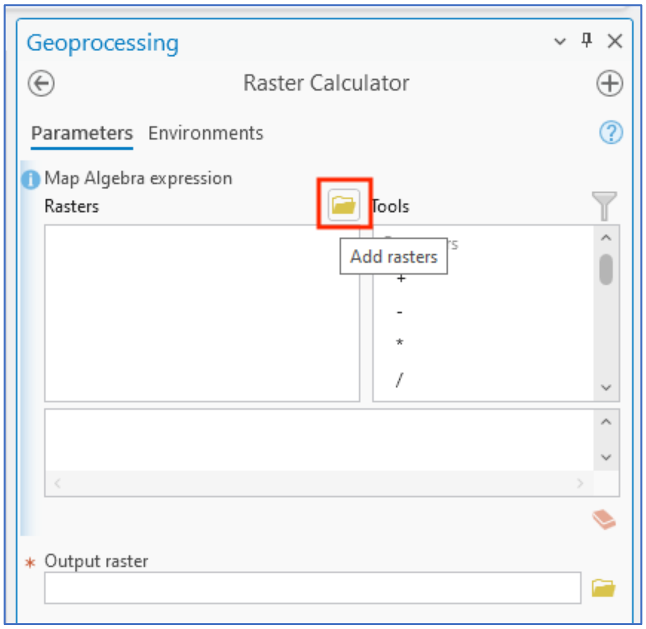


Figure 7 – Click the Add Raster icon

7. Navigate to your saved image. (For this exercise, we are using the GeoTIFF image that we exported in the Georeferencing with ArcGIS Tutorial.)

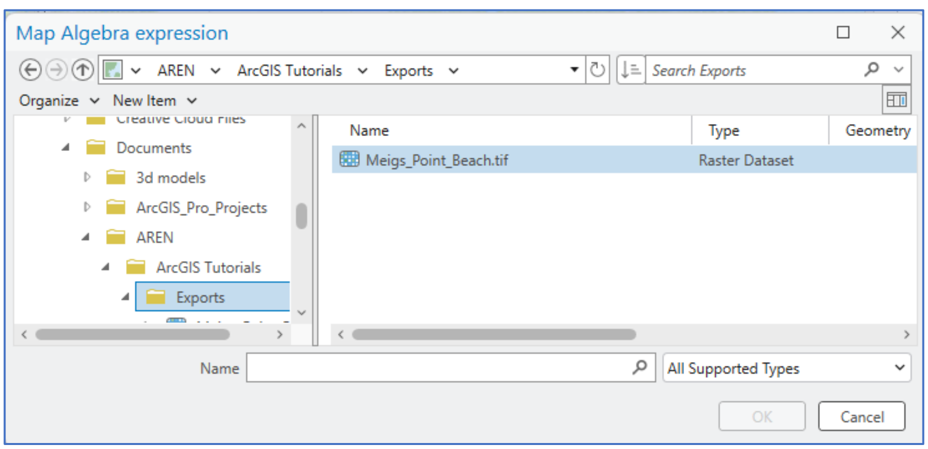


Figure 8 – Navigate to your image file

8. Double-click on the file name to open the individual red, green, and blue channel bands.

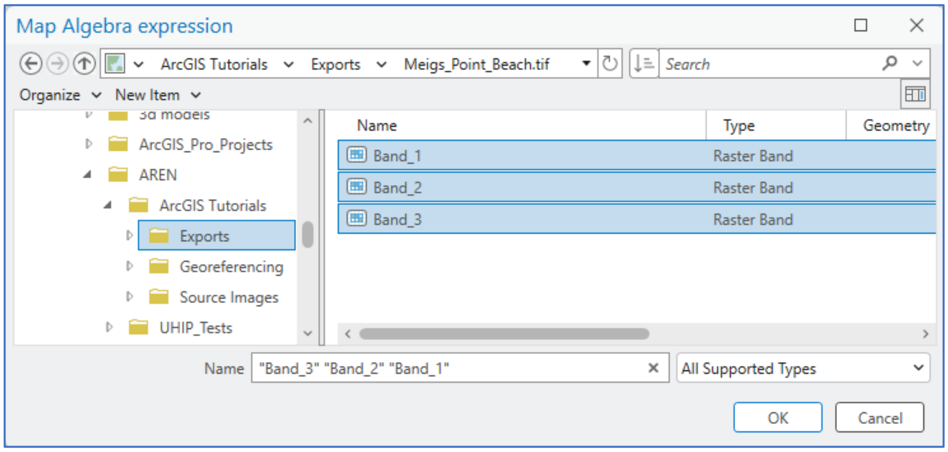


Figure 9 – Three color bands selected

9. Select all three bands and click OK

   The individual bands will now appear as rasters in the Rasters menu.

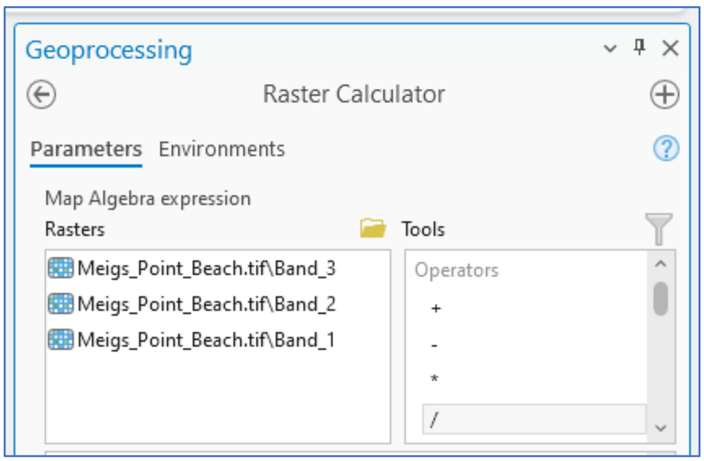


Figure 9 – Three color bands selected

The Raster labeled Band_1 is the Red channel of your image.

The Raster labeled Band_2 is the Green channel of your image.

The Raster labeled Band_3 is the Blue channel of your image.

Part Two: Use the Raster Calculator to create a Green Leaf Index.

The formula or *algorithm* we are using to create our Green Leaf Index is:

(2 * Green - Red - Blue) / (2 * Green + Red + Blue)

This formula is applied to the values in the three channels of each pixel in the image. The output will be a new grayscale or monochrome image with just one channel, and each pixel in the image will be assigned a new value that ranges between (–) 1.0 and 1.0.

10. Enter the following into the Raster Calculator box:

    ((2 * "*your_file.tif*\Band_2" - "*your_file.tif*\Band_1" - "*your_file.tif*\Band_3") / (2 * "*your_file.tif*\Band_2"+ "*your_file.tif*\Band_1"+ "*your_file.tif*\Band_3"))

    where *your_file.tif* is replaced with the name of your actual file.

    Tip: Type the open and closed parentheses marks. Note that there is an extra open and closed parentheses surrounding the whole equation. Use the following method for everything else: *Double-click* on an *Operator* from the **Tools** menu to add it to the equation, and *double-click* on the Raster file names to add them to the equation.

    In our example, the equation looks like this:

    ((2 * "Meigs_Point_Beach.tif\Band_2"- "Meigs_Point_Beach.tif\Band_1"- "Meigs_Point_Beach.tif\Band_3") / (2* "Meigs_Point_Beach.tif\Band_2" + "Meigs_Point_Beach.tif\Band_1" + "Meigs_Point_Beach.tif\Band_3"))

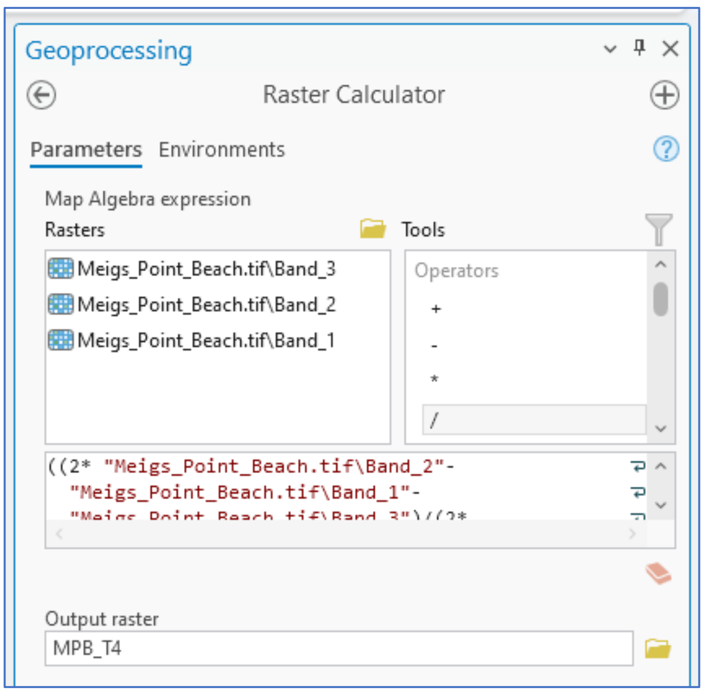


Figure 10 – Equation entered into Raster Calculator

11. When you have finished entering the equation, enter an output name and location for your **Output raster**

12. Click the Run Button

    If your equation was entered correctly, you should see a message saying the Raster Calculator completed. If not, you will get an error message. In this case. Check your equation for errors, and try again.

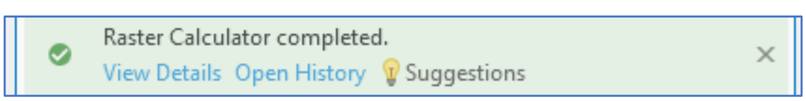


Figure 11 – Raster Calculator completed message

When successful, a new grayscale raster will appear in the map window and in the Contents Panel. This is a single-channel Green Leaf Index image.

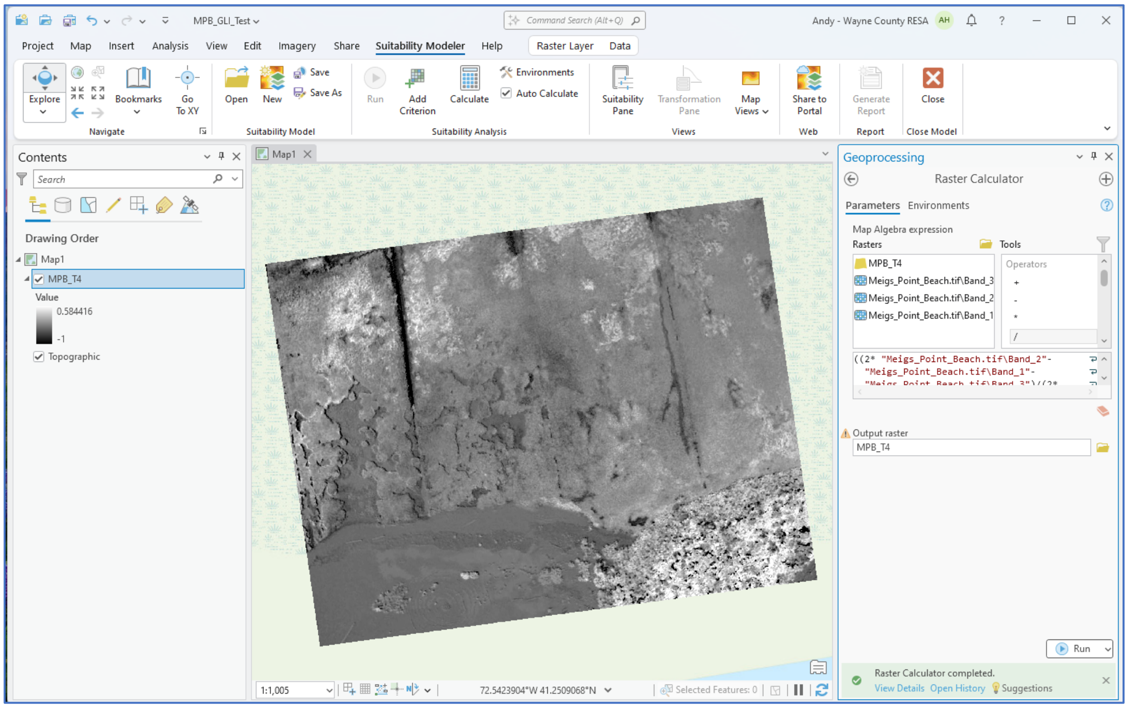


Figure 12 – Grayscale GLI image

Part Three: Symbolize the new GLI image

Next, we will colorize the image to make it easier to interpret using the symbology tools.

13. Right-click on the Layer name and select Symbology from the drop-down menu.

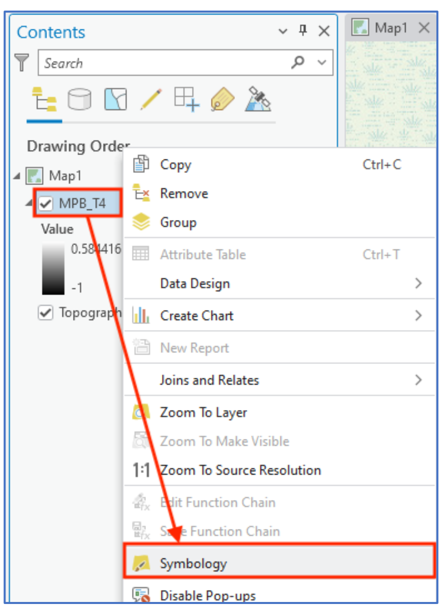


Figure 13 – Open the Symbology panel

The Symbology panel opens

The default Symbology type is Stretch, which works well with our data. This method clips the extreme ends of the data and stretches the remaining values so that they give a good range of light to dark.

14. Click on the Histogram button to open the histogram window.

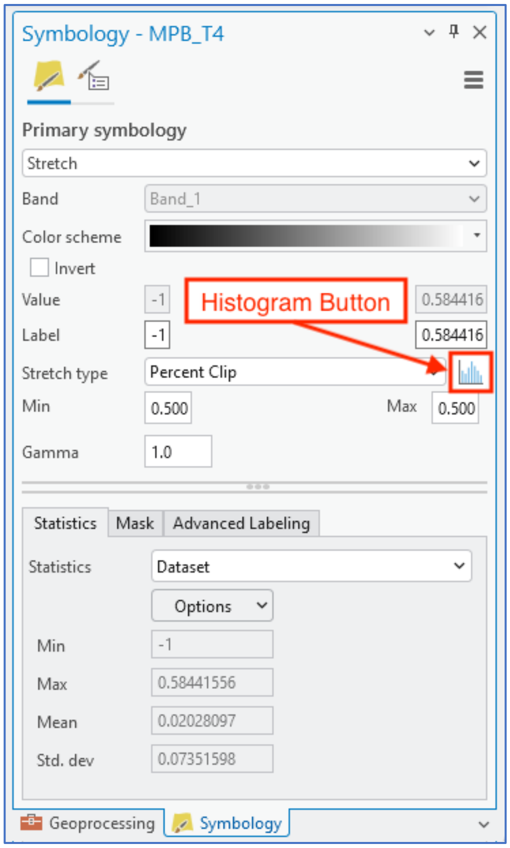


Figure 14 – Open the Histogram window

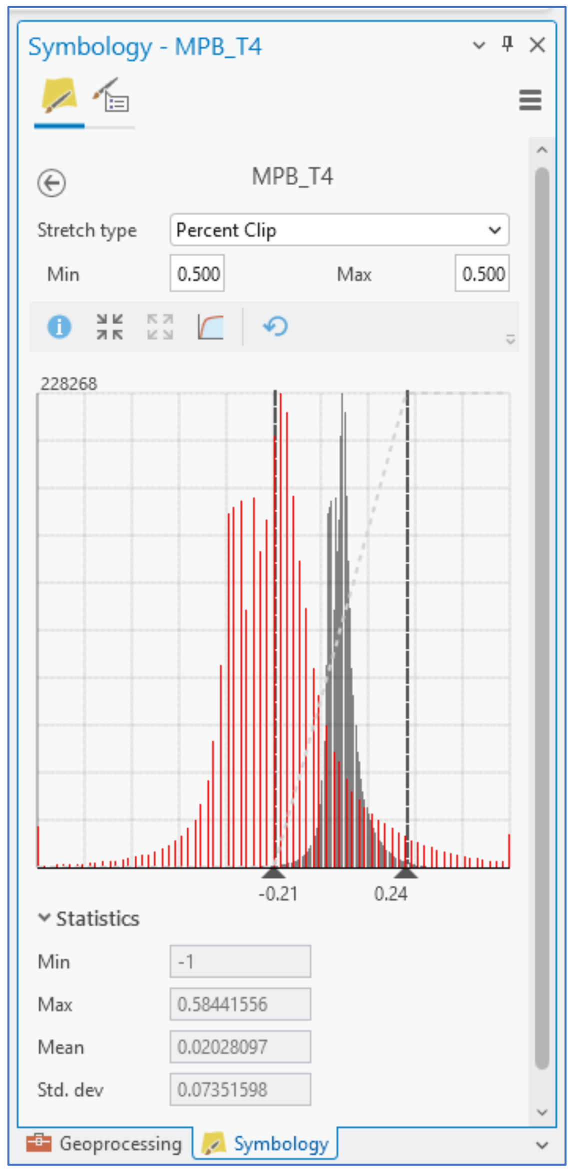


Figure 15 – The Image Histogram

The Gray lines in the histogram represent the actual distribution of pixel values.

Our actual values are largely clustered between -0.21 and 0.24. If you click the down arrow next to Statistics, you can see that the Minimum value in our data is -1 and the maximum is 0.58, both well outside of the clustered range. The Mean, 0.02, is very close to zero.

The red lines show the stretched distribution with the outliers clipped. This enhances the contrast in the overall image and limits the impact of outlying values.

15. Click the back arrow to return to the Primary symbology window

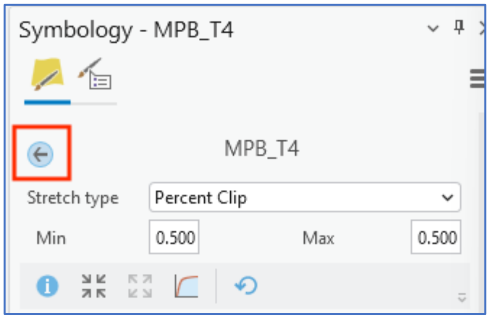


Figure 16 – Return to Primary symbology window

16. Click the color bar in the Color scheme window to select a color scheme.

    Scroll down until you see the "Condition Number" (Green - Yellow - Red) color scheme. Select that.

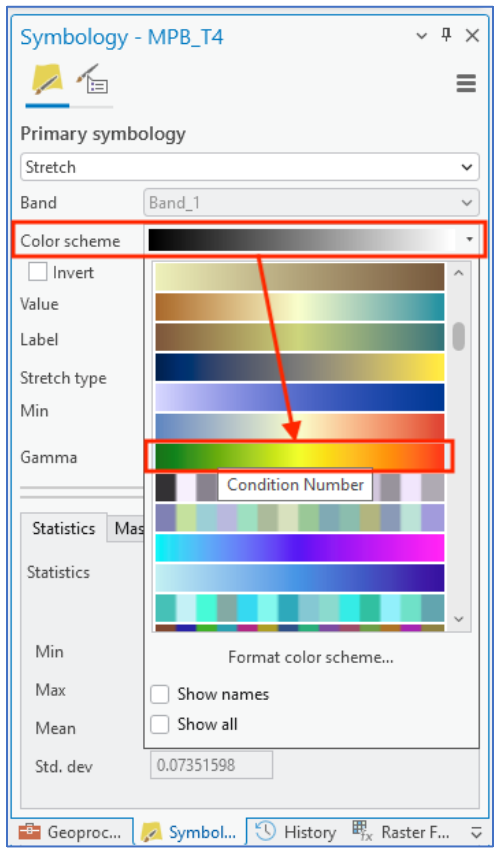


Figure 17 – Select a Color scheme

17. Check the box that says "Invert"

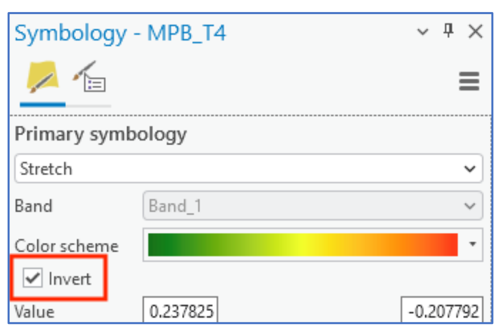


Figure 18 – Check the Invert option

Your image will now be symbolized with the color ramp.

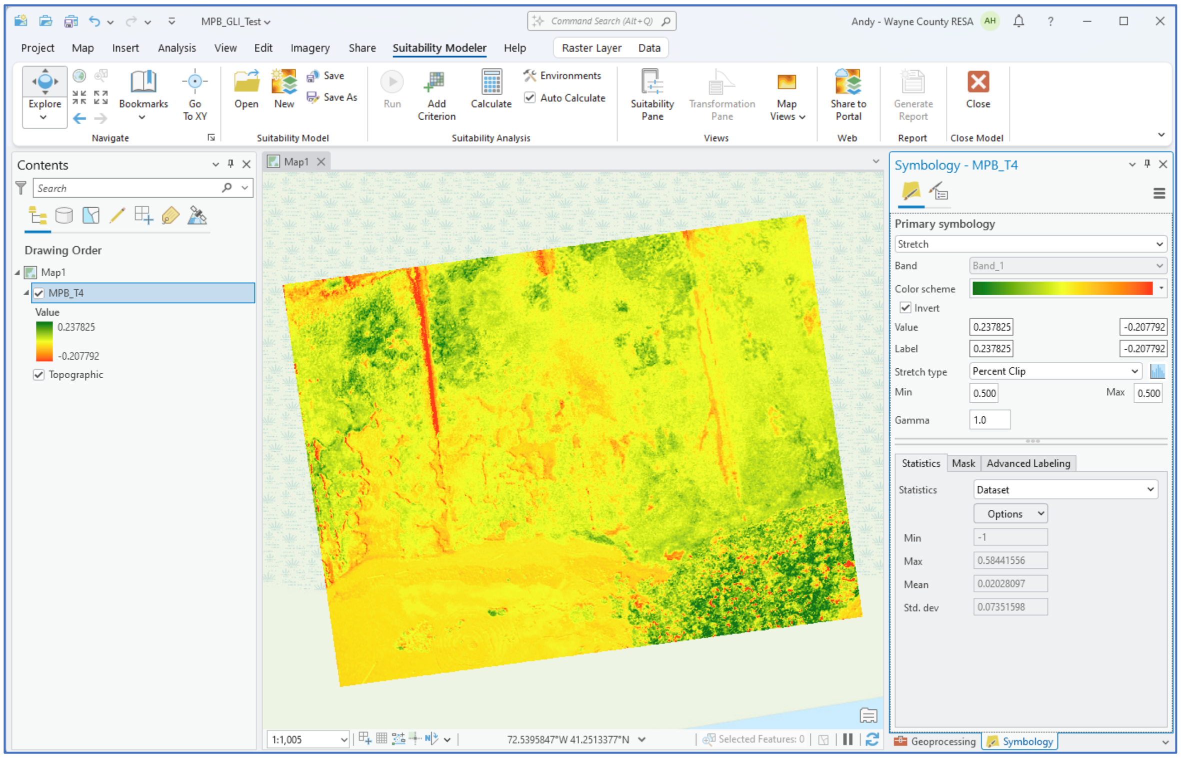


Figure 19 – GLI image with color ramp applied

You now have a colorized image where anything that is pale orange to red is less likely to be vegetation, and anything yellow to green is more likely to be vegetation.

Remember that in our index, the closer a value is to 1.0, the greener it is, and by inference, the more likely it is to be healthy vegetation. The closer a value is to -1.0, the less green it is, and by inference, the less likely to be healthy vegetation.

You can try different color ramps to see what effect they have on the image.

Part Four: Create a two value (dichotomous) image

In this particular image, many of the values are clustered near the center of the range (0.0) and it can be difficult to tell whether they lean toward vegetation or non-vegetation. We can change the symbology by creating a threshold value and symbolizing all the values above it with one color and all the values below it with another color. This creates a dichotomous (yes or no) image that can be useful in making quick assessments of land cover.

To make a dichotomous image:

18. Make a note of the current values in the **Value** and **Label** fields in case you want to return to them later. (See Figure 20)

19. Click in the **Value** fields and type “0.001” in the left field, and type “0” into the right field (see Figure 21).

20. Click in the **Label** fields and type “>0” in the left field, and type “<0” in the right field (see Figure 21).

This moves the endpoint colors to zero for Red and 0.001 for Green, effectively forcing any pixel less than zero to appear red any pixel greater than zero to appear green.

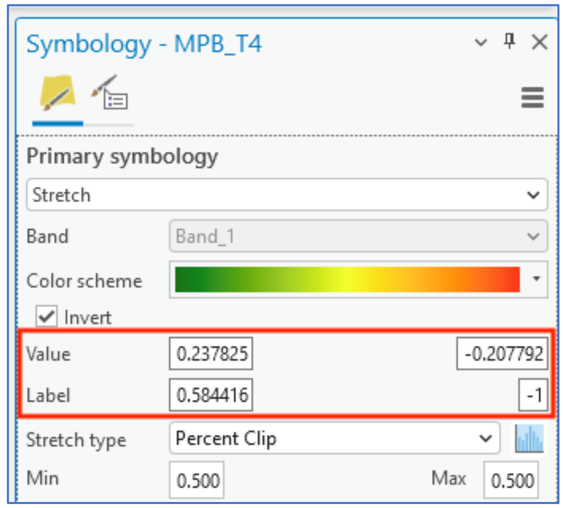


Figure 20 – Current Values and Labels

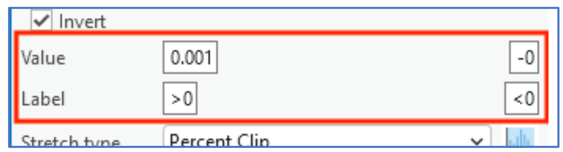


Figure 21 – Adjusted Values and Labels

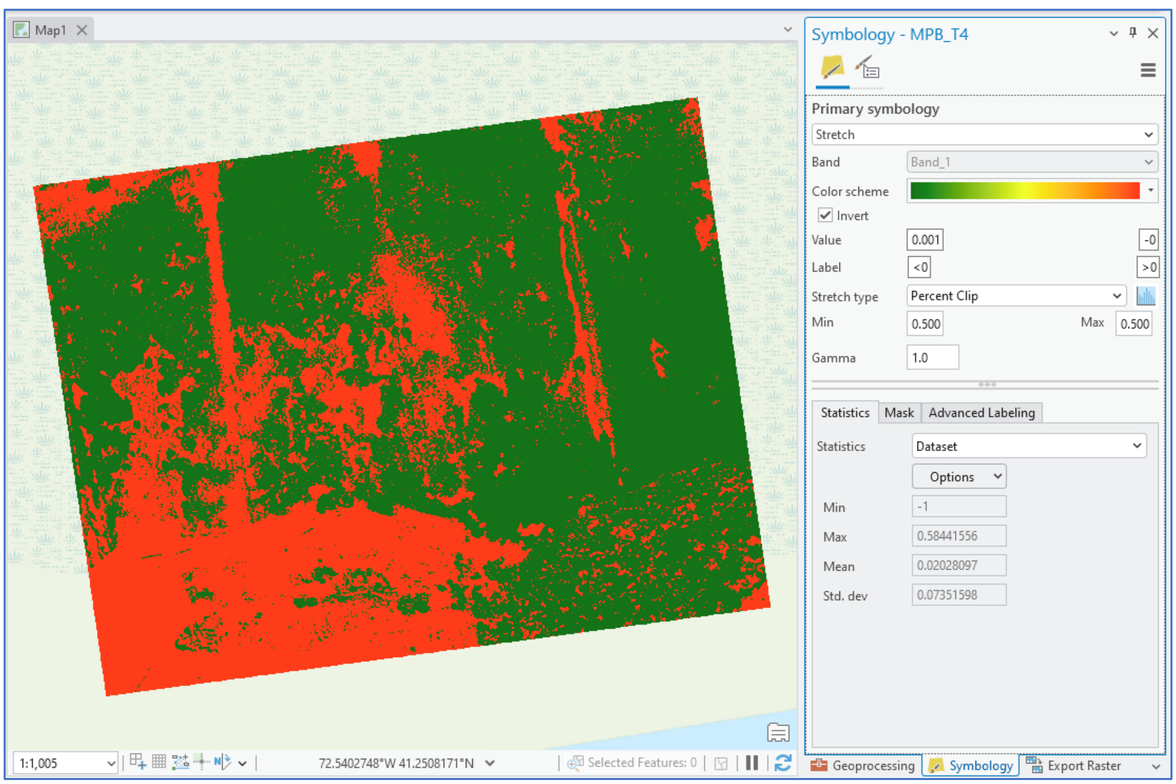


Figure 22 – New dichotomous GLI image

In a dichotomous image like this, it is better to have one color be light and one dark. The contrast helps to distinguish the features. We’ll fix that in the next step.

21. Click on the Color scheme panel and select a simple light-to-dark color ramp, such as Bathymetry 3 (as seen in Figure 23).

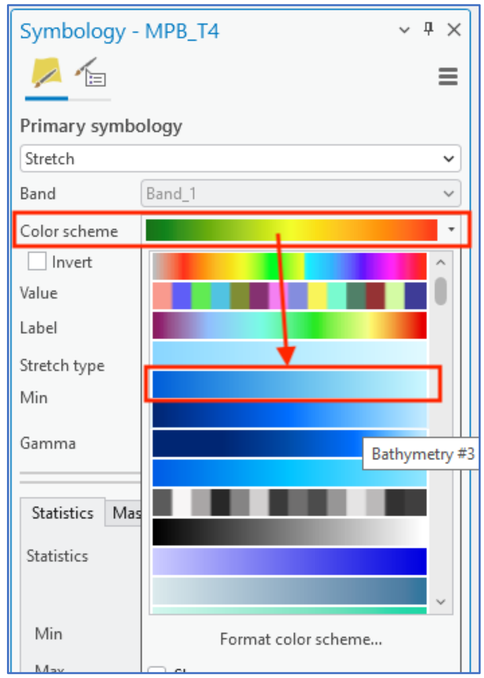


Figure 23 – Bathymetry #3 color scheme

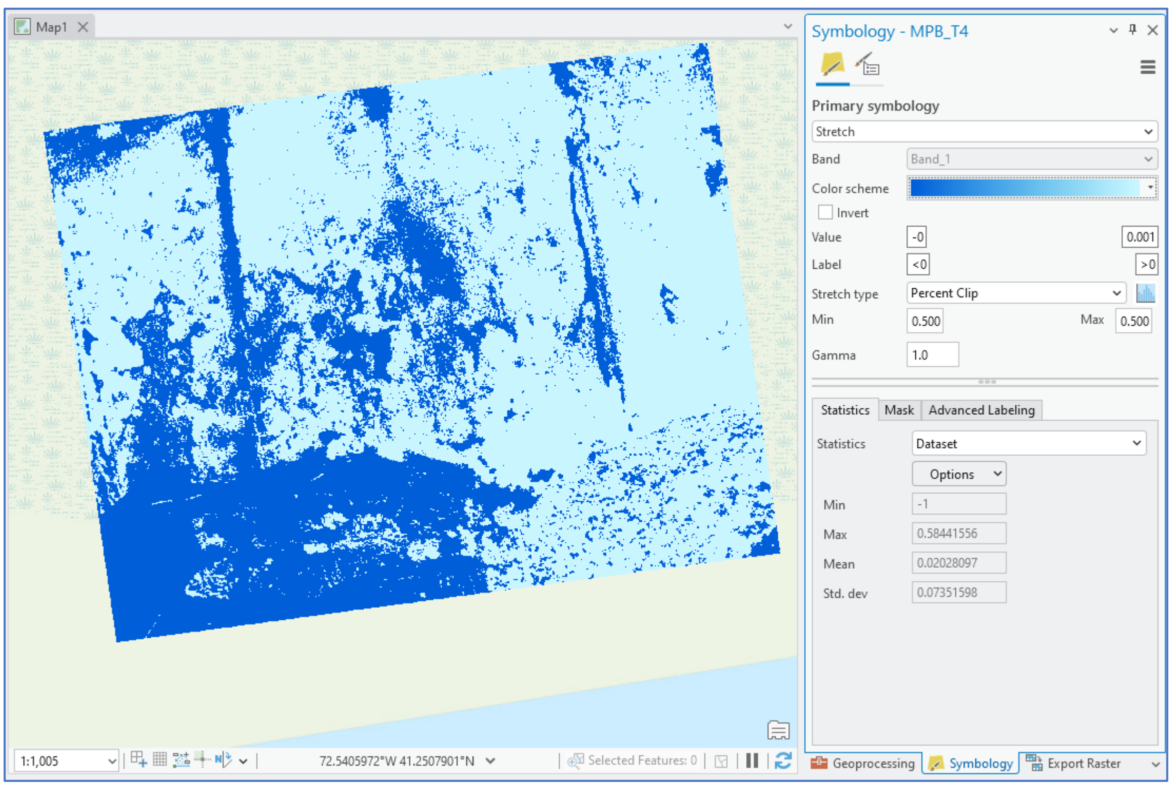


Figure 23– Dichotomous GLI with high-contrast color scheme

Part Five: Export your image as a GeoTiff

When you are satisfied, you can export your image as a new GeoTIFF. To export your image:

22. Right-click on the layer name in the Contents Panel and select Data > Export Raster

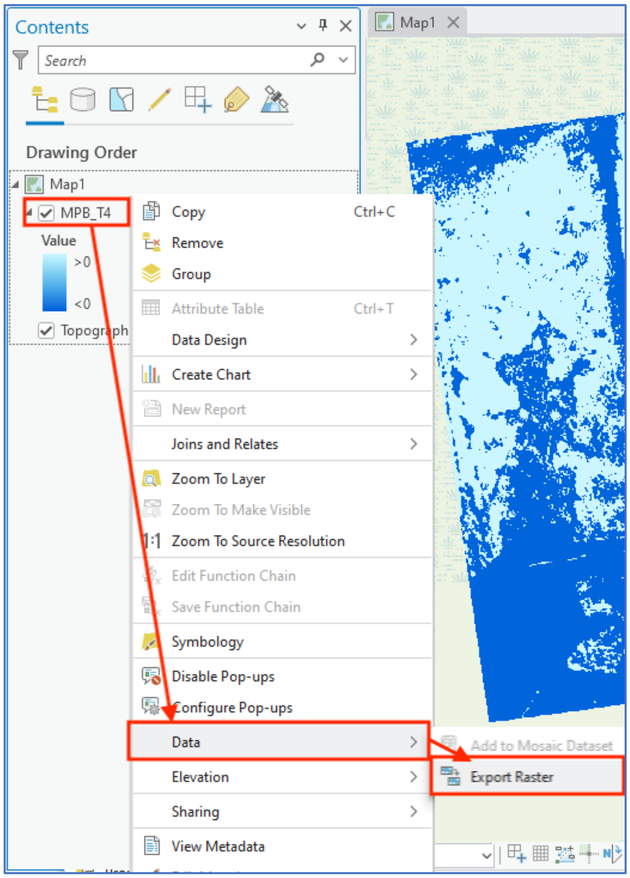


Figure 24 – Open the Export Raster panel

The Export Raster Panel will open.

23. In the Export Raster panel (Figure 25):

- Select your Output Raster Dataset file name and location
- Set Output Format to TIFF
- Be sure that the Spatial Reference System is set to WGS_1984_Web_Mercator_Auxiliary Sphere
- Scroll to the bottom of the window, open the Render Settings dropdown, and check "Use Renderer" and "Force RGB" (Figure 26 - below)

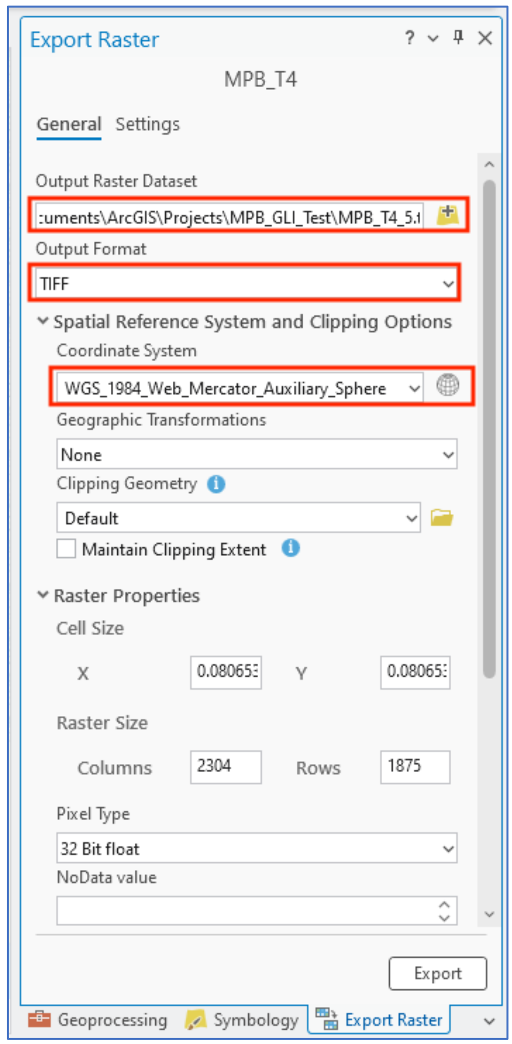


Figure 25 – Export Raster Settings (part 1)

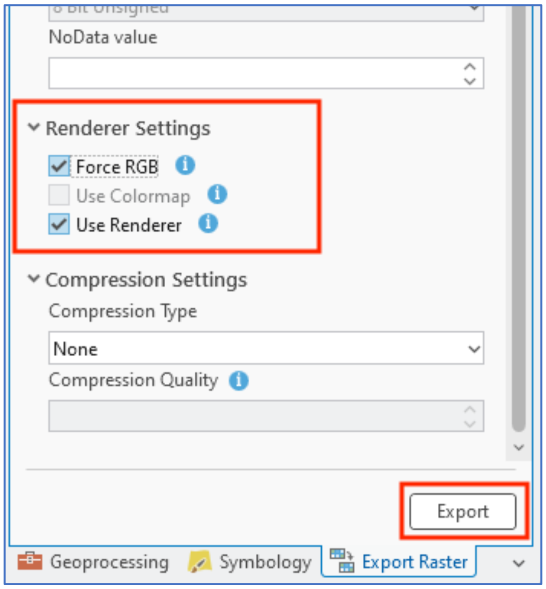
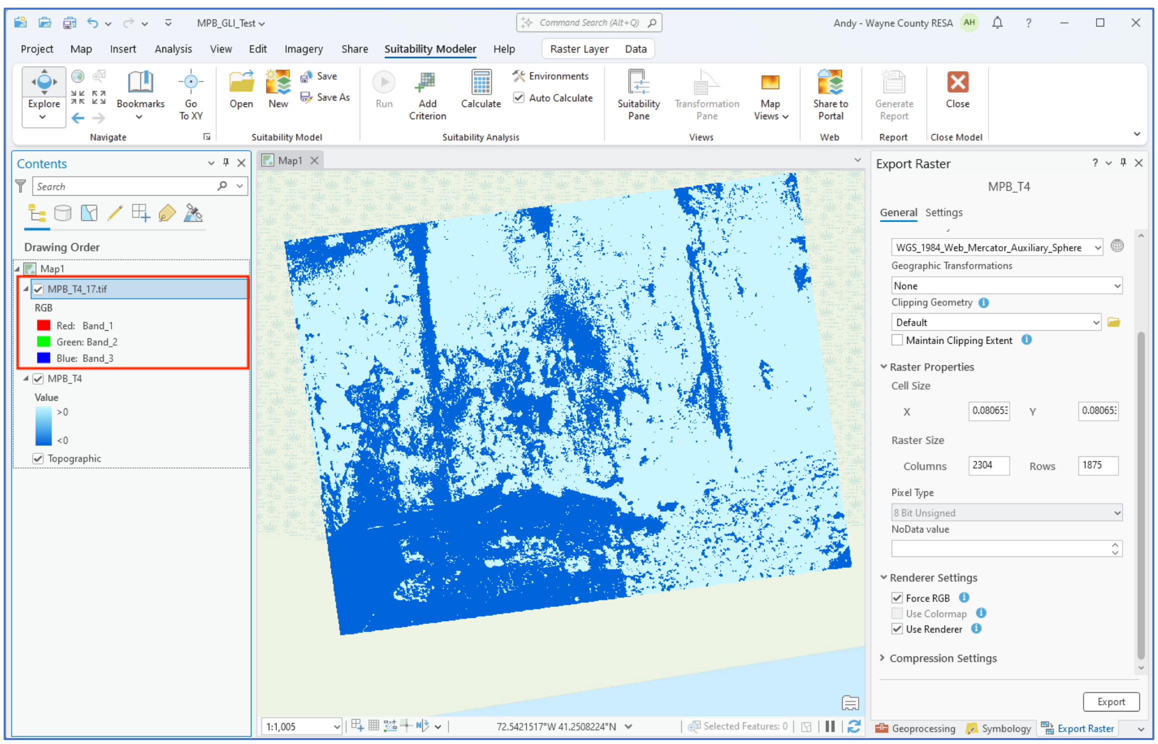


Figure 26– Export Raster Settings (part 1)

24. Click Export

    The new Raster is added to your map.



25. Save your project.

The GeoTIFF you created maintains its spatial properties and can be opened in other spatially aware applications, such as QGIS and Google Earth.