Spectral Transforms: Simple Ratio, NDVI, and Tasseled Cap Transformation of Madison Wisconsin

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Simple Ratio Transformation

To calculate the simple ratio, we took the reflectance of the red band and divided it by the reflectance of the near-infrared (NIR) band. This allows us to interpret the spectral contrast across these bands. The brighter the pixel the larger the ratio is between red and NIR reflectance. The darker the pixels are, the closer the ratio between the two bands is 1. This analysis will be able to convey how much bright NIR is in comparison to the red band

In Figure 1, The Cursor Value Tool is used to determine the DN values of each band in a linked location within the Madison area. For this interpretation, the cursor was placed over a wooded area. In the ratio image, this exact location is very bright and the pixel value is 2.803640. This indicates that the reflectance in the NIR band is nearly three times brighter than the red band. This makes logical sense since the cursor value also indicates that the DN value of the red band is 8077 and the DN value of the NIR band is 22645; 22645/8077 = 2.803640.

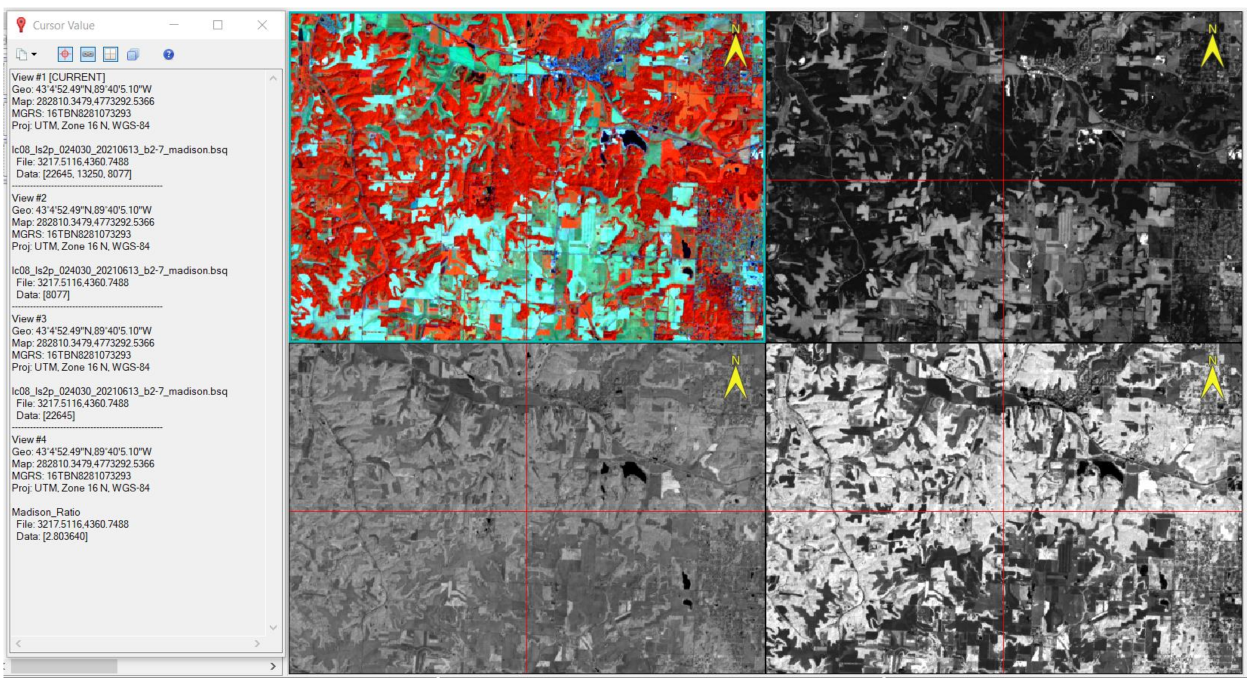

Figure 1: Scene of the Madison area in False color (top left), red band (top right), NIR (bottom left), simple ratio (bottom right), with DN value example

Table 1: Example of DN values across various images

Image	Reflectance (DN Value)
False Color Image	[22645, 13250, 8077]
Red Band	[8077]
NIR Band	[22645]
Ratio	[2.803640]

NDVI Transformation

NDVI stands for Normalized Difference Vegetation Index and is a metric to measure the health of vegetation in a standardized format. This index is created by the following:

$$NDVI = \frac{NIR - red}{NIR + red}$$

NDVI is determined by taking the difference of NIR and red band reflectance and dividing that number by the sum of NIR and red band reflectance. This index, allows us to determine how healthy vegetation is across the landscape. This is because green vegetation absorbs nearly all of the red band for the process of photosynthesis. The red that is absorbed is then scattered throughout the structure of the leaf and is brightly displayed in the NIR Band.

In this process, we reduced multiple bands (red and NIR) into a single band (Figure 2). The final product is an NDVI band where each pixel provides a NDVI value relating to the health of the vegetation. This metric is often used to indicate green cover, biomass, leaf area index (LAI), and chlorophyll content. In this band, the brighter the pixel the healthier the vegetation is. Conversely, the darker the pixels represent unhealthy vegetation or non-vegetated features. An alternative method to interpreting NDVI is to measure it on a scale between “-1” to “1”. The closer NDVI is to “1”, the healthier the vegetation is. If the NDVI value approaches 0, NIR reflectance is becoming diminished and the red color is becoming more reflective. This indicated that the vegetation is unhealthy. If the NDVI is between “0 through -1”, that that pixel represents non-vegetation. Examples of this include water. The NDVI band is significantly brighter than the simple ratio band and provides less contrast. With NDVI, we can determine the species and community distribution, phenological cycles, vegetation health, change detection, and greening trends linked to global warming.

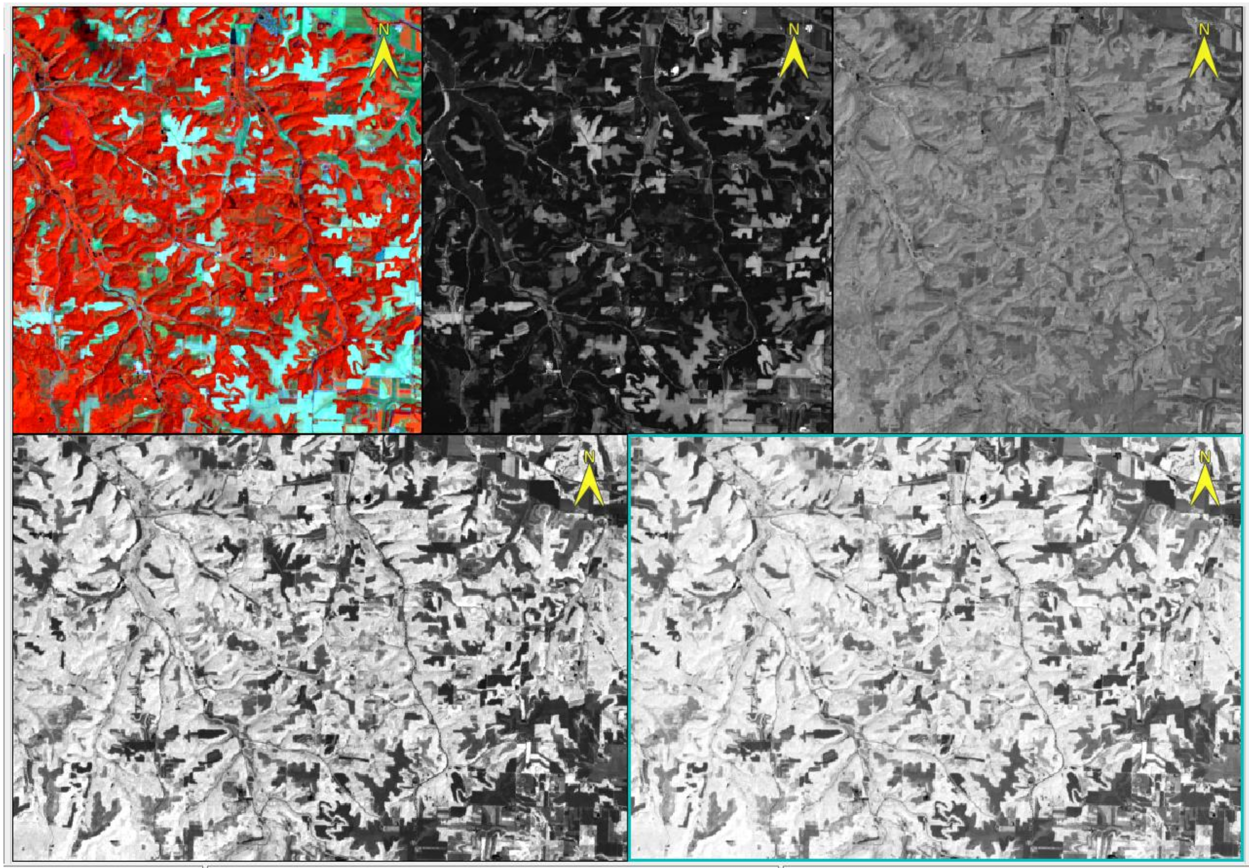

Figure 2:Scene of the Madison area in False color (top left), red band (top center), NIR (top right), simple ratio (bottom left), NDVI (bottom right).

Analyzing Results

Table 02 describes the minimum, maximum, and mean values of the NDVI of Urban, Water, Forest, and Cropland classifications across the Madison area. The minimum and maximum provide good insight into the range of NDVI values that may be present within a landcover classification, but also may not be the most reliable. For example, the water classification has a max NDVI value of 0.355715. This would indicate that vegetation is growing somewhere within this classification. Although this is possible (e.g. algae), the maximum value is a result of user error. Several pixels with positive NDVI values were accidentally captured in this classification.

A better metric to interpret NDVI values of classification is to examine the mean (Table 2). The mean indicates the average NDVI value across that landcover classification. Forests had the highest NDVI mean with 0.476589, and cropland followed with 0.302232. Both of these metrics are reasonable as healthy forests tend to have a high stable NDVI value while cropland NDVI value can vary based on the status of the field (i.e, cropland field may not have emerged from the ground or could have been harvested). Water has an average mean of -0.006117. This is reasonable as well since negative NDVI values indicate a non-vegetive classification. Interestingly, the urban classification has a low but positive NDVI value. This can be perplexing as Urban areas are considered to be non-vegetative. However, as pixel classifications were being made for urbanization, neighborhoods with a heavy amount of trees were captured in the classification. Figure 3 is an example of an Urban ROI that was captured where there was a high number of trees present. The mixture of bright blue pixels and red pixels indicates an urbanized area that has a large number of trees. Because of this the urbanized classification received a higher NDVI mean since it is also accounting for the vegetation with the neighborhood.

Table 2: Pixel summary of Urban, water, forest, and cropland classification

Landcover Classification	Min	Max	Mean	StdDev
Urban	-0.01946	0.482646	0.208612	0.105662
Water	-0.03976	0.355715	-0.006117	0.007512
Forest	0.203595	0.568438	0.476589	0.02605
Cropland	0.038654	0.575184	0.302232	0.108999

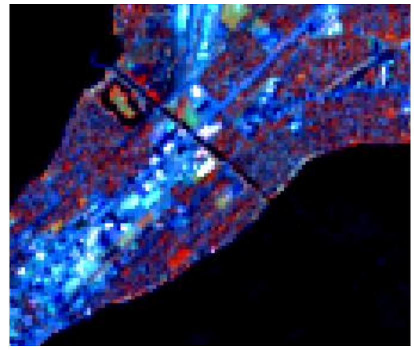

Figure 3: Urbanized area with high amounts of vegetation

Tasseled Cap Transformation

The Tasseled Cap Transformation is a way to convert multiple bands of raster data into two to three components. The benefit of this transformation is that it allows us to interpret the health of vegetation without having to interpret all the bands within a given raster. Specifically, this transformation allows us to evaluate the landscape through three components: Brightness, Greenness, and Wetness (Figure 4). These values are determined by applying a specific coefficient (i.e. weight) to the pixel value (DN) across every individual band and then summing up the values. In the Brightness band, the brighter the pixel the more reflectance it will show. When pixels in the Brightness band are dark, they will show less reflectance. Similarly, the brighter the pixels are in the greenness band, indicates more vegetation and identifies the health of the vegetation. Areas, where the pixels are dark, indicate less vegetation in this greenness band. Finally, the bright the pixels are in the wetness band, the more moisture is present within that pixel. Conversely, the darker pixels in this band indicate no moisture.

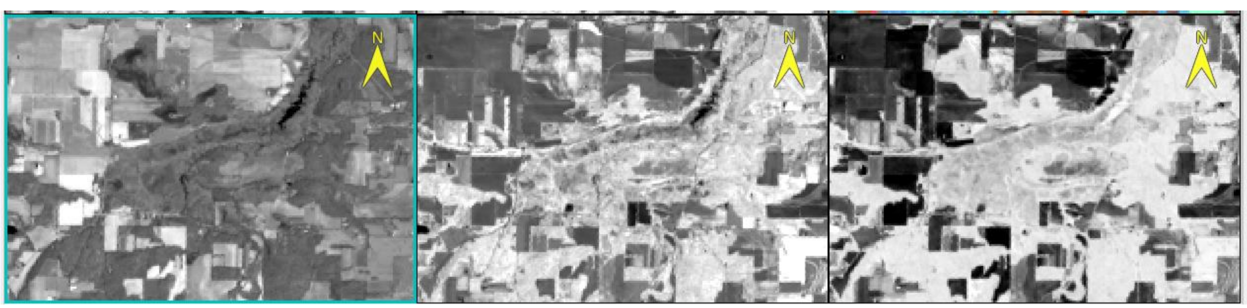

Figure 4: Tassel Cap Transformation as described in three individual bands: Brightness (left), Greenness (center), Wetness (right)

Difference between Simple Ratio, NDVI, and Greenness

The largest distinction that I notice between simple ratio, NDVI, and greenness is within the simple ratio image and. In this image, the pixels appear much darker than the rest of the image. I can distinguish the correlation of brightness across all pixels but I trouble to distinguish the gray tones in the simple ratio band. NDVI and Greenness both appear very similar. The Greenness band appears to have a slightly darker gray tone but not nearly as contrasting as the simple ratio band. Something that may be causing the differences between the simple ration bands compared to the NDVI and Greenness bands is how the bands are calculated. The simple ratio band is simply displaying the ratio of the red band to the NIR band. Although this knowledge, is insightful, it does not provide enough description of what is occurring on the landscape. NDVI normalizes the pixel values across the red and NIR red bands while the Greenness provides a normalized representation for how "green" vegetation using all available bands.

Plotting Red Band vs Near-Infrared Bands

The graph of Landsat Red vs NIR can be described as an upsidedown triangle where the point starts near the origin (Figure 5). The Soil Line can be identified in this process (i.e. there are no pixels in the bottom right portion of the graph). There are numerous trends that we can interpret from this plot. Water (blue) has very low reflectance in the red and NIR band and are shown in the lowest portions of the graph. Urban areas (yellow) closely trend closer to the soil line. We can interpret this to mean that urban areas typically have a one-to-one relationship between the Red Band and NIR Band. Cropland classification (red) has the largest variation of pixels classification in the red band to NIR band comparison. In this classification, the majoring of the pixel values range from 1,500 to 2,000 in the red band while the NIR reflectance ranges from 1,500 to 2,000. This observation is reasonable as land classification can vary based on how landowners manage their land (e.g. harvest vs. not harvested). Finally, the forest classification (green) has the majority of the pixel near the top left portion of the scatter plot. Therefore, forests have a rather flow reflectance in the red band but are highly reflective in the NIR Band.

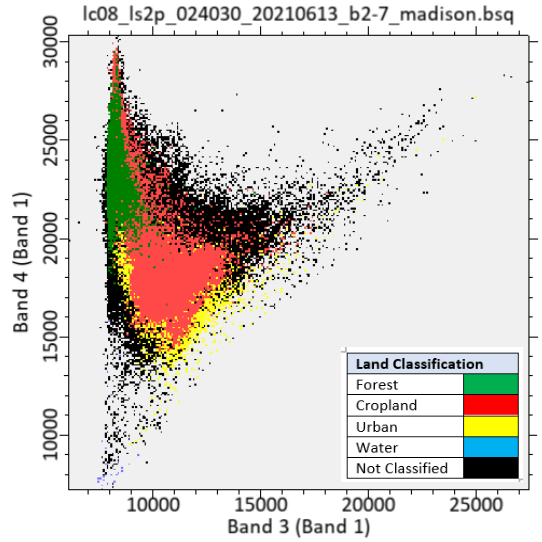

Figure 5: Scatter Plot of DN values between the red band and NIR band

Plotting Red Band vs Near-Infrared Compared to Brightness vs Greenness

The scatter plots between the Landsat red vs. NIR and Brightness vs. Greenness are very similar. The most apparent difference between these two plots, is the Brightness vs Greenness are tilted in comparison to the Landsat Red vs NIR plot (Figure 6). The Brightness vs. Greenness plot is considered to be a tassel cap. With this in mind, the Brightness vs. Greenness land classifications correlate positively to the land classification in the Landsat plot. However, the Brightness vs. Greenness plot is easier to interpret pixel classification. In this plot, you can clearly distinguish how land classifications relate to the pixel DN values. Conversely, the urban classification (yellow) is harder to distinguish from the cropland in the Landsat red vs NIR plot.

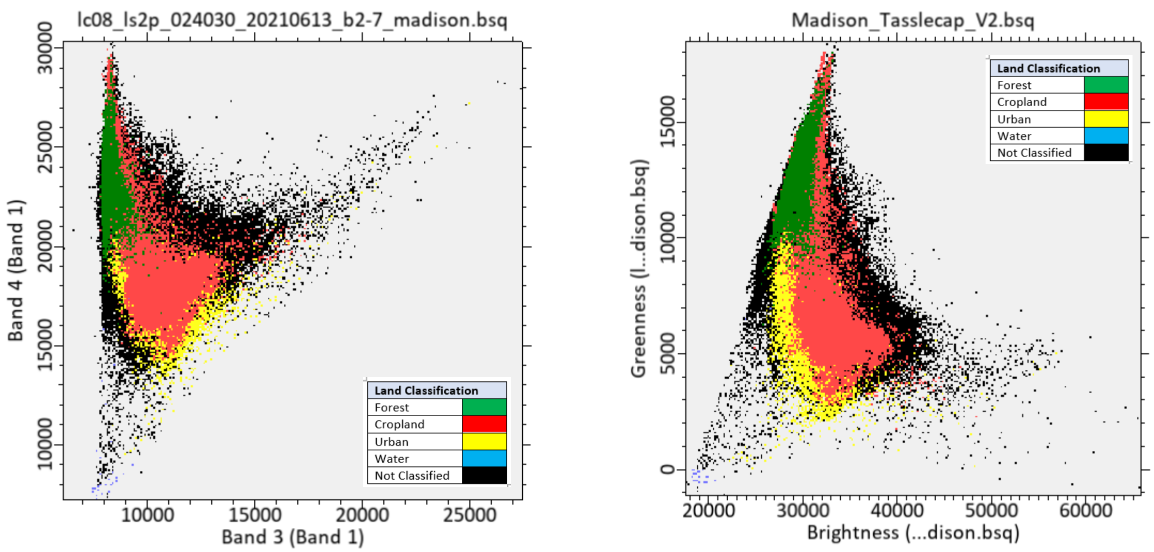

Figure 6: Scatterplot comparison of Red Band vs. NIR Band and Tassel Cap Brightness vs Greenness

Co-Spectral Plots

Of the multiple co-spectral plots, Tasseled Cap Wetness vs Greenness is the best plot to use when distinguishing between forest, urbanization, cropland, and water. In Figure 7, the landcover classifications are clearly defined. Pixels that have high Greenness values and low wetness can be classified as Forests. Cropland would typically be classified with moderate to low wetness values and moderate greenness values. Urban pixels have the lowest wetness value, except for water. This is because urban areas are typically not established in large bodies of water. Therefore, very few wetness values are present in this classification. Urban areas will also typically have low greenness values, but may occasionally have moderate levels of greenness (as seen in Figure XX). Greenness may be higher in urban areas if the ROI captured built-up areas with high amounts of vegetation (e.g. trees) present. Water has the lowest values and is located with the mean values located near the bottom right corner of the scatter plot.

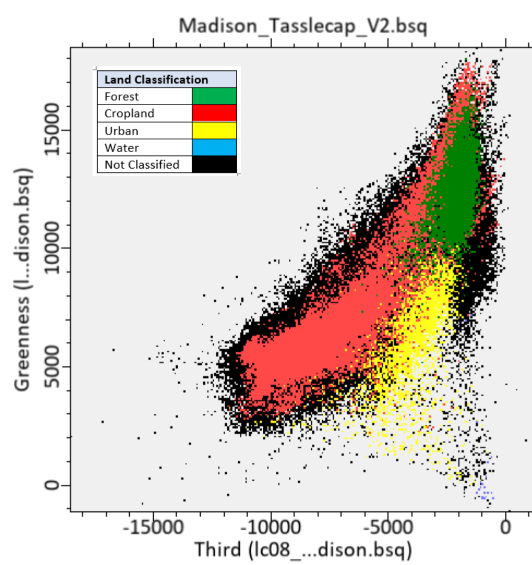

Figure 7: Tassel Cap Wetness vs Greenness

Interpreting Plots to Determine Vegetation

Of all the co-spectral plots, the Tasseled Cap Wetness vs Greenness plot is the best graph to use to determine how much vegetation is present, but the NDVI transformation would be the best image to visually inspect when determining how much vegetation is present.

In the Tasseled Cap Wetness vs Greenness plot, we can distinctly see the trend where forests and cropland would be present. This is largely due to the wetness band that is available in this plot. Being able to distinguish wetness, allows us the pinpoint urban area and intuitively understand the water will have the lowest values. Therefore, all other pixels are very likely to represent vegetation. This is outlined by the purple outline in Figure 8.

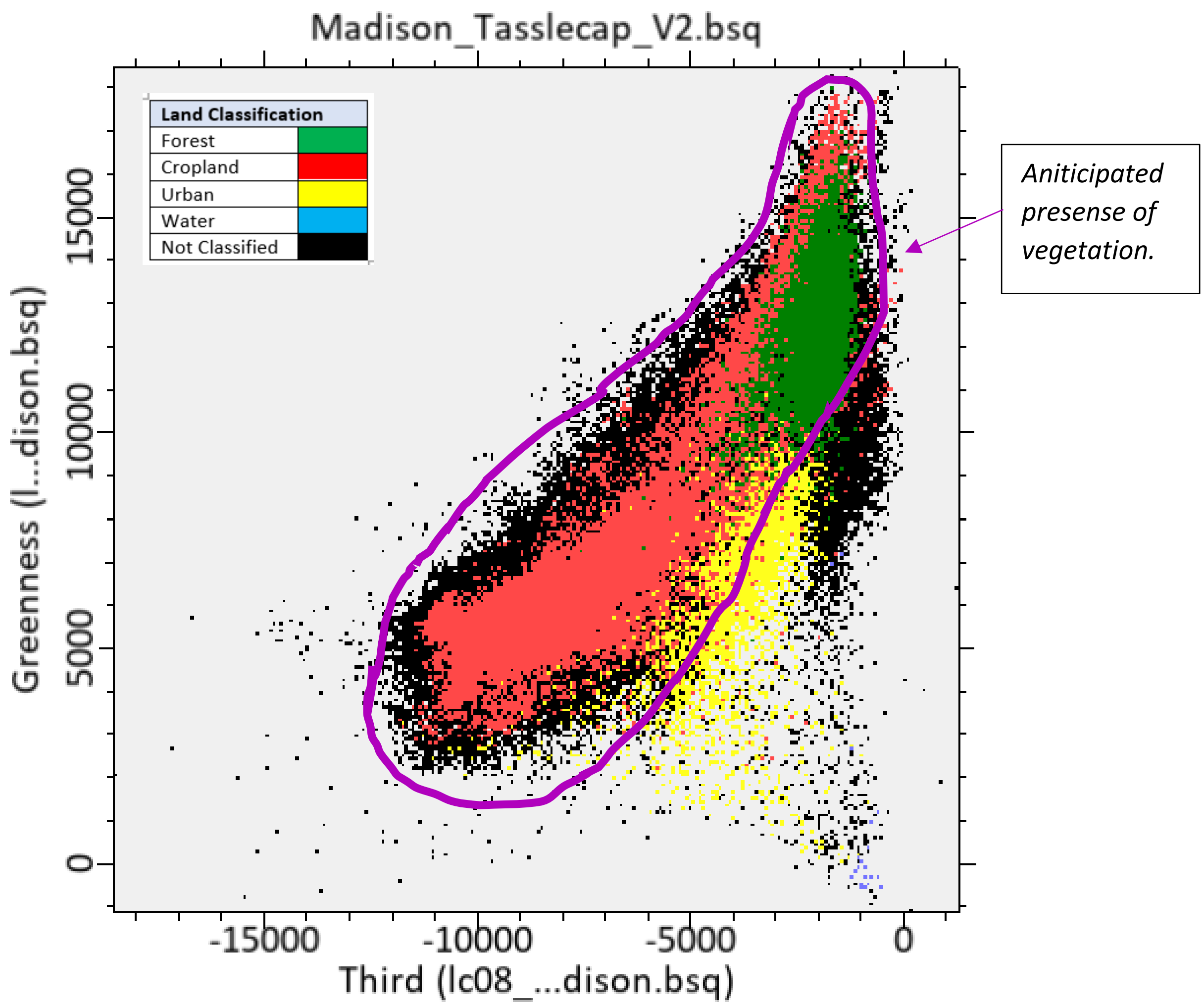

Figure 8: Tassel Cap Wetness vs. Greenness with anticipated vegetation presence outlined in purple

The best band for determining which band would be best for interpreting the amount of vegetation would be the NDVI transformation band. This is because this NDVI value identifies vegetation based on how bright the pixels are in the image. Therefore, it is easy to distinguish where vegetation is present using this transformation. It is worth noting that numerous band brightness can be correlated to the amount of vegetation. The greenness band and NDVI look very similar as the images are compared side by side. However, the contrast in NDVI is slightly more than in the Greenness band (Figure 9). As a result, it is easier to distinguish how much vegetation is present across the landscape.

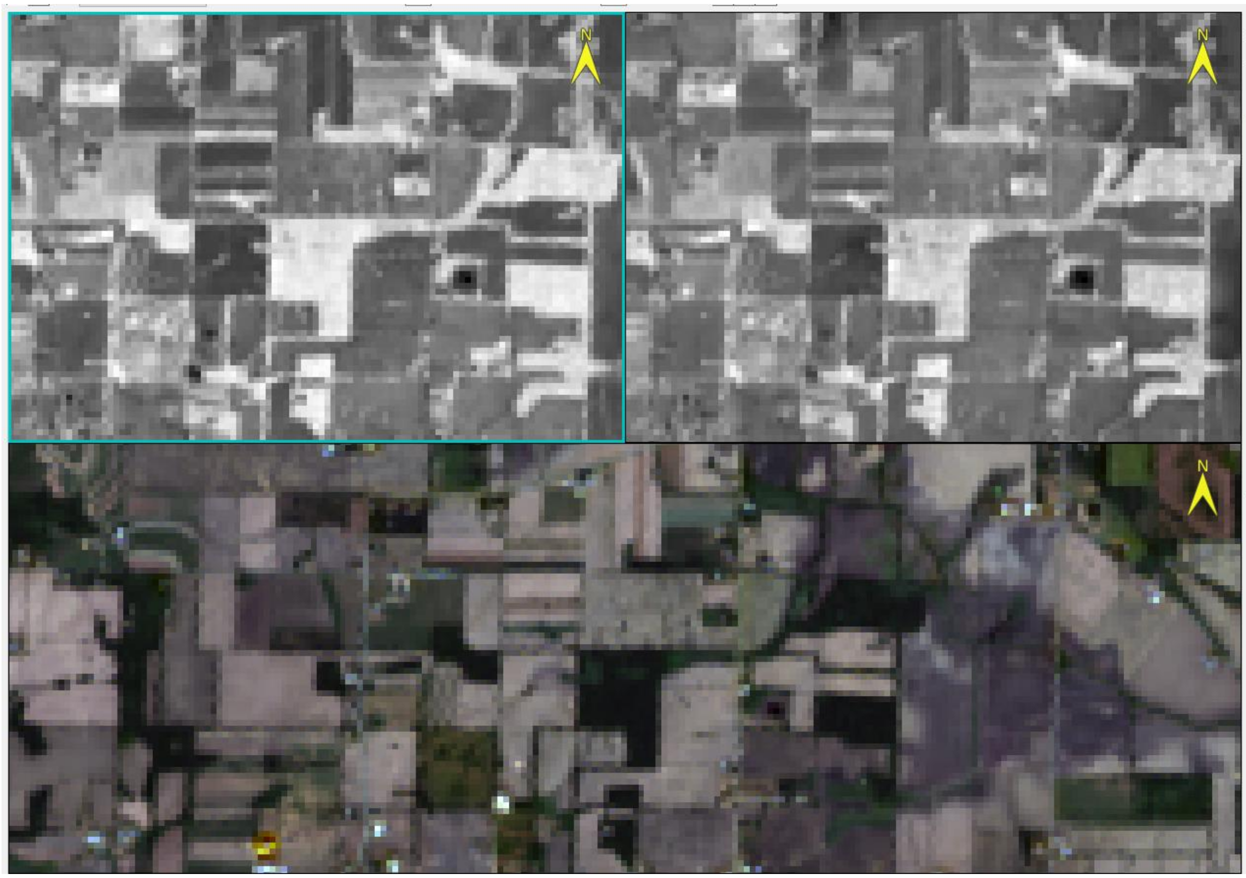

Figure 9: Comparison of NDVI (top left), Greenness (top right), and True Color (bottom) in the Madison area