Burn Ratios for Fire Severity Mapping

Objectives

- *Compare and contrast the spectral reflectance of burned areas and the spectral reflectance of healthy forests.*
- *Create an estimate of burn severity using pre- and post-fire satellite data.*
- *Understand how multispectral data can help us map forest fires and estimate burn severity.*

Background and Data

The **2016 Sand Fire** occurred in the Angeles National Forest east of Los Angeles, California. It began on July 22, 2016. The fire was not contained until August 3, at which point it had burned an estimated 35,000 acres. The burn extent is within the yellow circle in Figure 1.

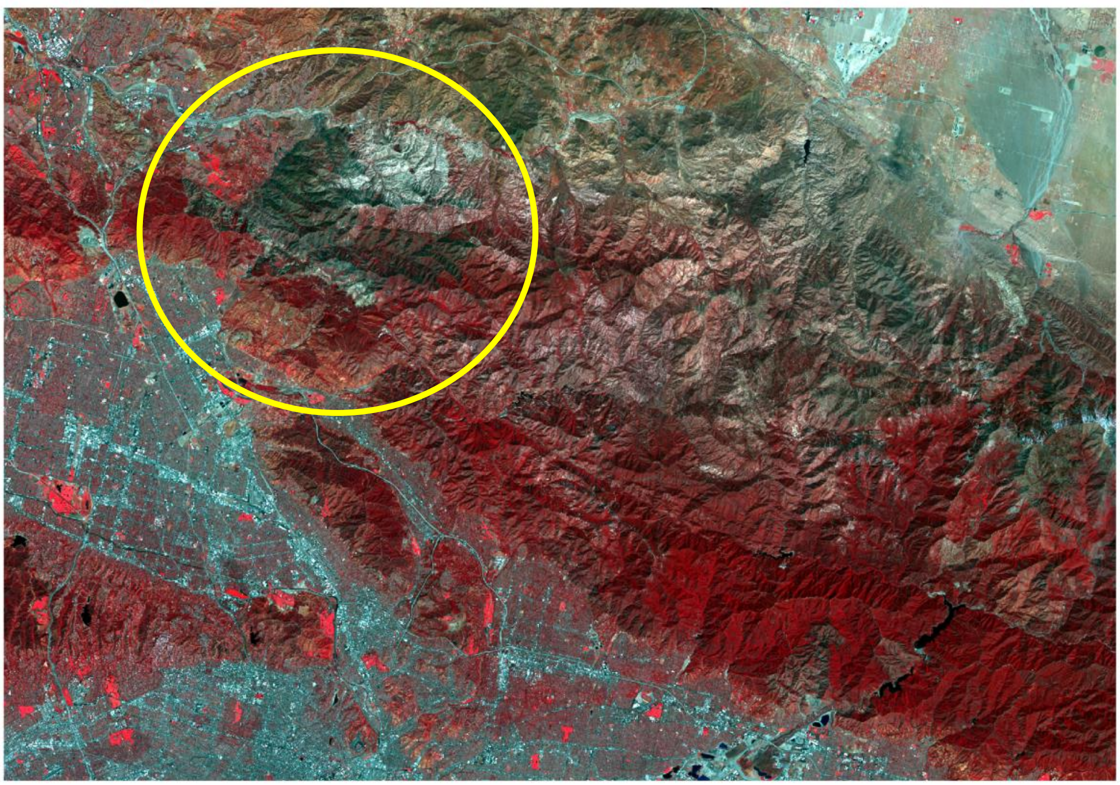


Figure 1. Extent of fires shown in false color, post-fire Landsat 8 Operational Land Imager (OLI) data.

You have been provided with two Landsat 8 Operational Land Imager (OLI) scenes. The pre-fire scene (**sand_fire_pre_4_17_2015.tif**) was collected on April 17, 2015 while the post-fire scene (**sand_fire_post_4_12_2017.tif**) was collected on April 22, 2017. These data have been processed to surface reflectance. The band designations are provided in Table 1.

Table 1. Landsat Operational Land Imager (OLI) spectral bands.

Band Number	Spectral Range (µm)
Band 1	Blue Edge (0.43 to 0.45)
Band 2	Blue (0.45 to 0.51)
Band 3	Green (0.53 to 0.59)
Band 4	Red (0.64 to 0.67)
Band 5	NIR (0.85 to 0.88)
Band 6	SWIR1(1.57 to 1.65)
Band 7	SWIR2 (2.11 to 2.29)

Your goal is to estimate burn severity using the normalized burn ratio (NBR) and differenced normalized burn ratio (dNBR). NBR is calculated from a single image as follows:

$$\text{NBR} = \frac{NIR - SWIR2}{NIR + SWIR2}$$

Once NBR has been calculated for both a pre- and post-fire image, dNBR is calculated as follows:

$$\text{dNBR} = \text{NBR}_{\text{pre}} - \text{NBR}_{\text{post}}$$

Once dNBR is calculated, you will categorize the result into varying levels of burn severity using the values in Table 2.

Table 2. dNBR value reclassification.

Category	Range of dNBR Values
Unburned	< +.1
Low Severity	+.1 to +.27
Moderate Severity	+.27 to +.66
High Severity	> .66

Figure 2 compares the spectral curves for burned and unburned areas through the visible, near infrared (NIR), and shortwave infrared (SWIR) spectral ranges.

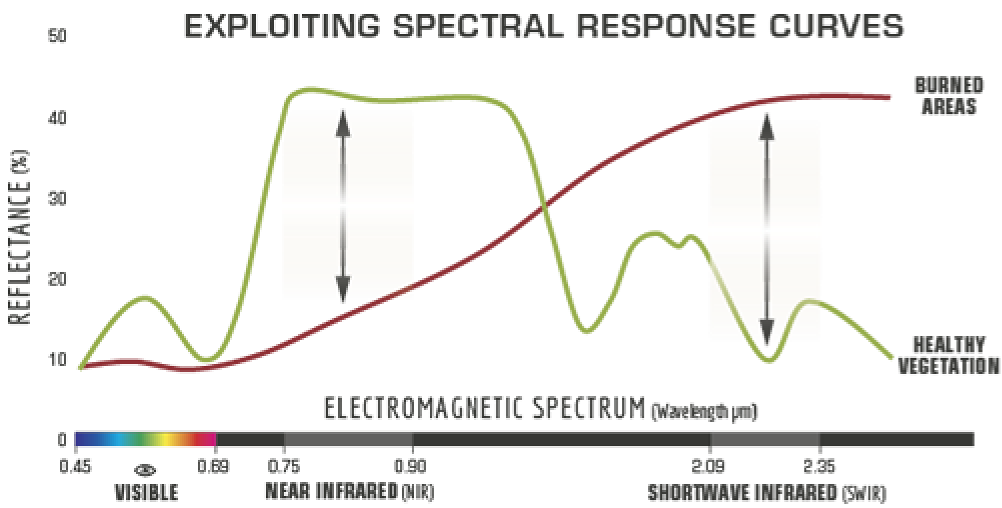
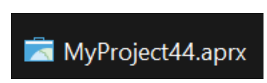


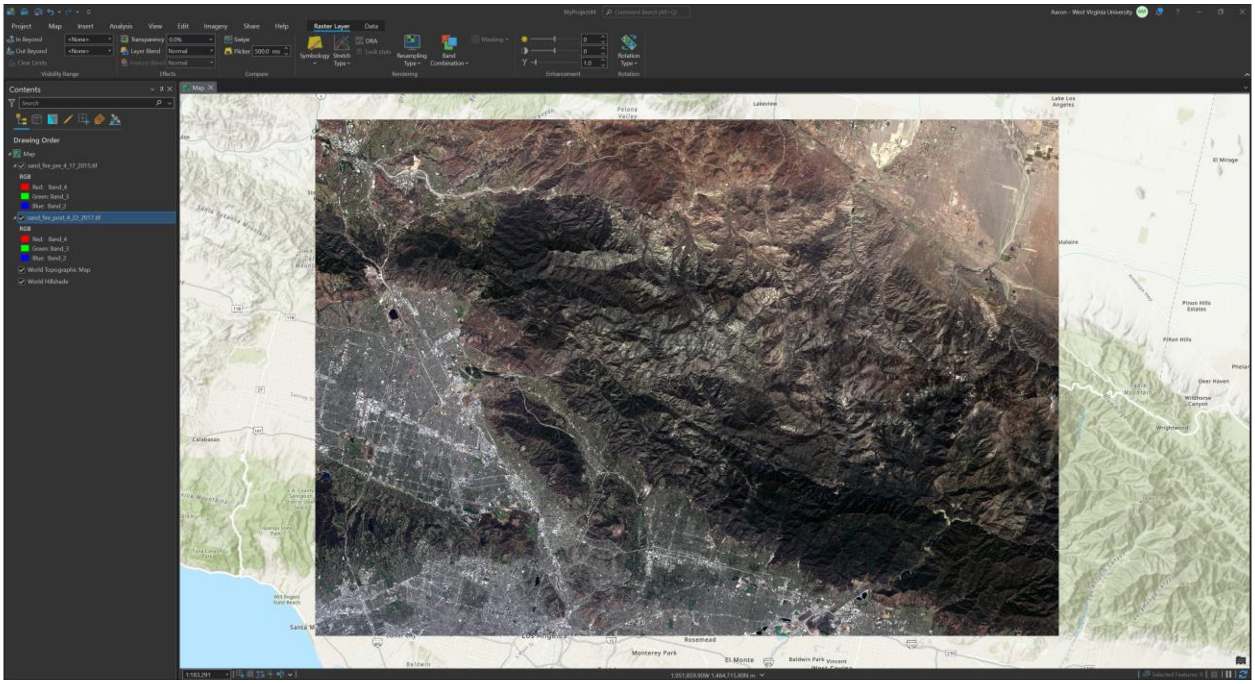
Figure 2. Spectral curve for burned and healthy vegetation. Source: https://www.earthdatascience.org/courses/earth-analytics/multispectral-remote-sensing-modis/normalized-burn-index-dNBR/; US Forest Service

Discussion Point 1: Why are the NIR and SWIR ranges useful for differentiating burned areas and healthy vegetation?

Analysis

1. Log into the computer using the following account information:
    a. Username: GnGDevCourse
    b. Password: Summer2024!
2. A folder titled "burnSeverity" has been placed on the desktop. Open the folder and double-click the MyProject44.aprx file. This will launch the ArcGIS Pro software. The software state should look like the screen capture provided below.

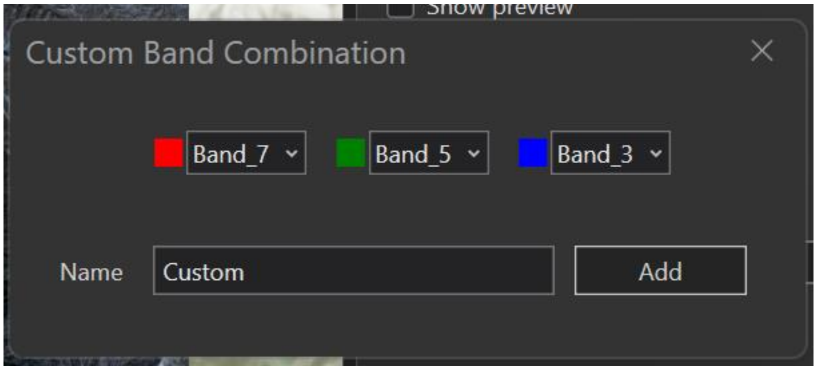




3. The imagery is currently displayed as follows: the red band is mapped to the red channel, the green band is mapped to the green channel, and the blue band is mapped to the blue channel. This is termed as simulated true color image and mimics our perception of color. Toggle between the two images to see if you can locate the fire extent based on changes in the imagery between the two dates. This can be accomplished by clicking on the check box next to the layer name in the Contents Pane.

Discussion Point 2: How easy is it to see the extent of the fire using this band combination?

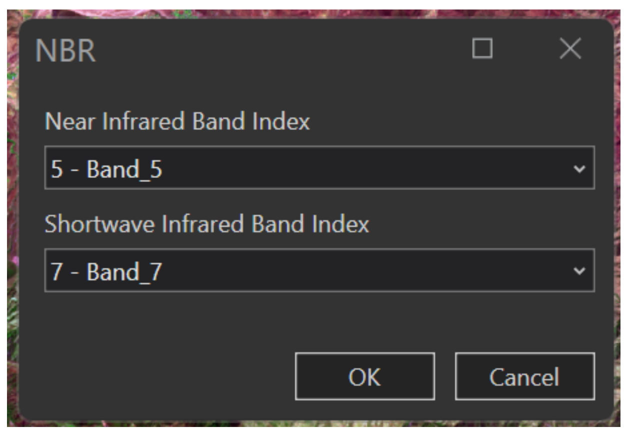
4. Change the displayed band combinations as follows (repeat this process for both images).
    a. Make sure one of the images is selected in the Contents Pane.
    b. Navigate to the Raster Layer tab.
    c. Select Band Combinations followed by Custom.
    d. Change the band combinations to match the example below. The SWIR2 band is mapped to the red channel, the NIR band is mapped to the green channel, and the red band is mapped to the blue channel.



5. Toggle between the two images to see if you can locate the fire extent based on changes in the imagery between the two dates using this new band combination. This can be accomplished by clicking on the check box next to the layer name in the Contents Pane.

Discussion Point 3: How easy is it to see the extent of the fire using this band combination? Is it easier or more difficult than using a simulated true color image?

6. Calculate the NBR separately for each image as follows:
   a. Make sure one of the images is selected in the Contents Pane.
   b. Navigate to the Imagery Tab.
   c. Select Indices followed by NBR.
   d. In the pop-up window, make sure that Near Infrared Band Index is set to Band_5 and Shortwave Infrared Band Index is set to Band_7.
   e. Click OK to execute the tool.
   f. Repeat this process for the other image.

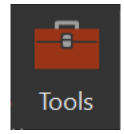


Discussion Point 4: In the post-fire NBR, the burned area should show up as dark. Can you explain why this is the case based on the band ratio used and the spectral reflectance of burned areas vs. healthy forested areas?

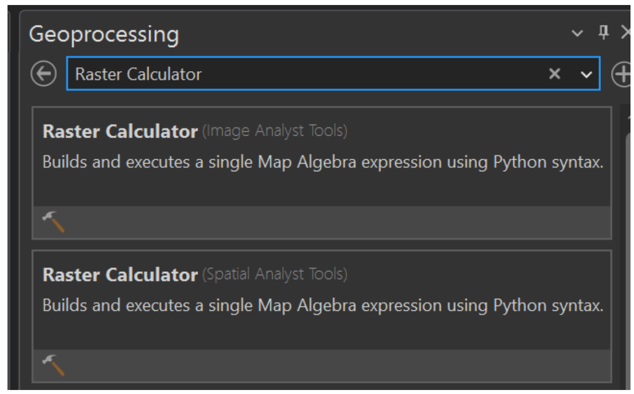
7. Calculate the dNBR using the pre- and post-fire NBRs that you just calculated.

   a. Navigate to the Analysis Tab.

   b. Select the Tools Icon. This will open the Geoprocessing Pane.

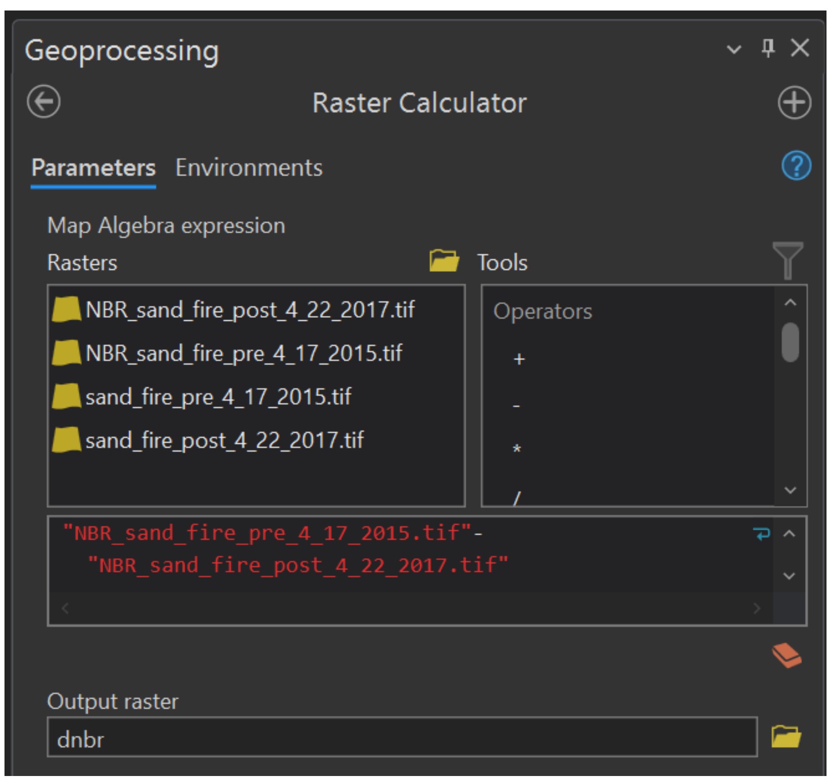


   c. In the Geoprocessing Pane search for "Raster Calculator". Select the Raster Calculator tool (you can use the Image Analyst or Spatial Analyst version; they are the same).



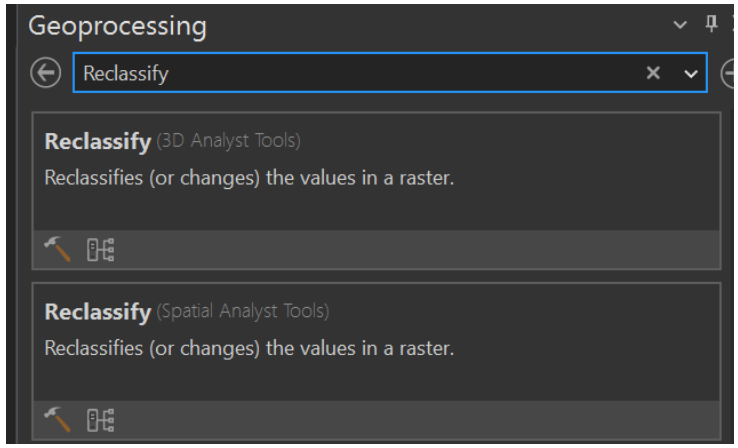
   d. Use Raster Calculator to calculate the dNBR by subtracting the post-fire NBR from the pre-fire NBR.

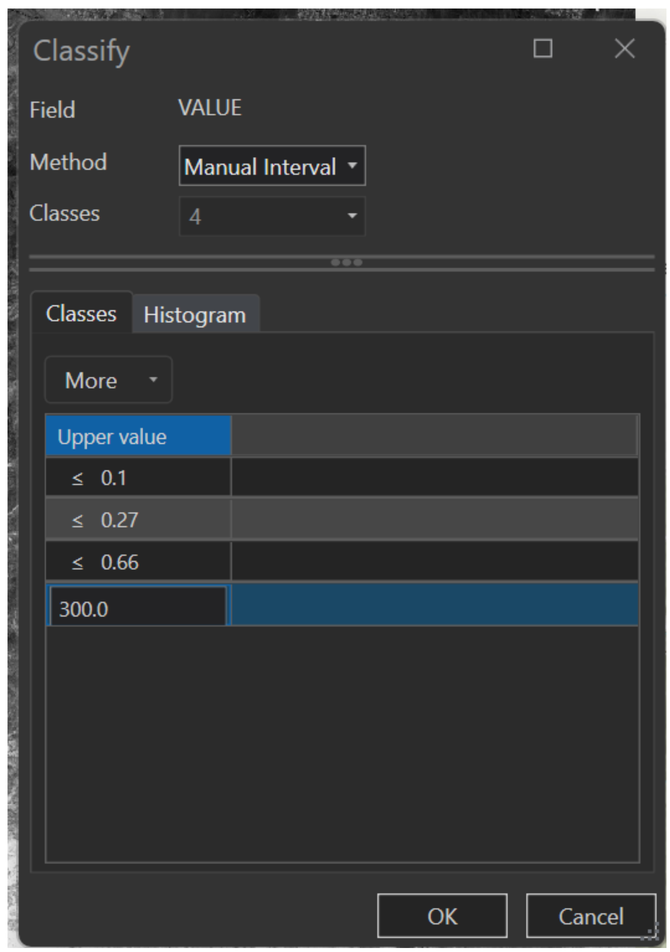
   e. Name the output dNBR and click Run to execute the tool. The output should be added to the map once the process executes.

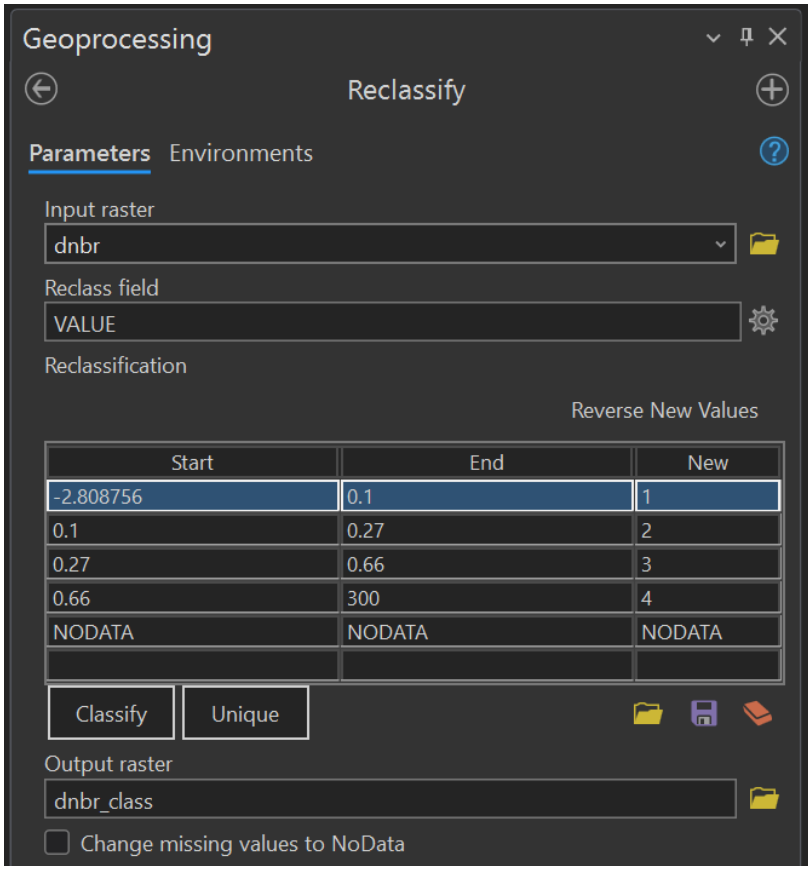


Discussion Point 5: In the dNBR, the burned area should show up as bright. Can you explain why this is based on the band ratio used and the spectral reflectance of burned areas vs. healthy forested areas?

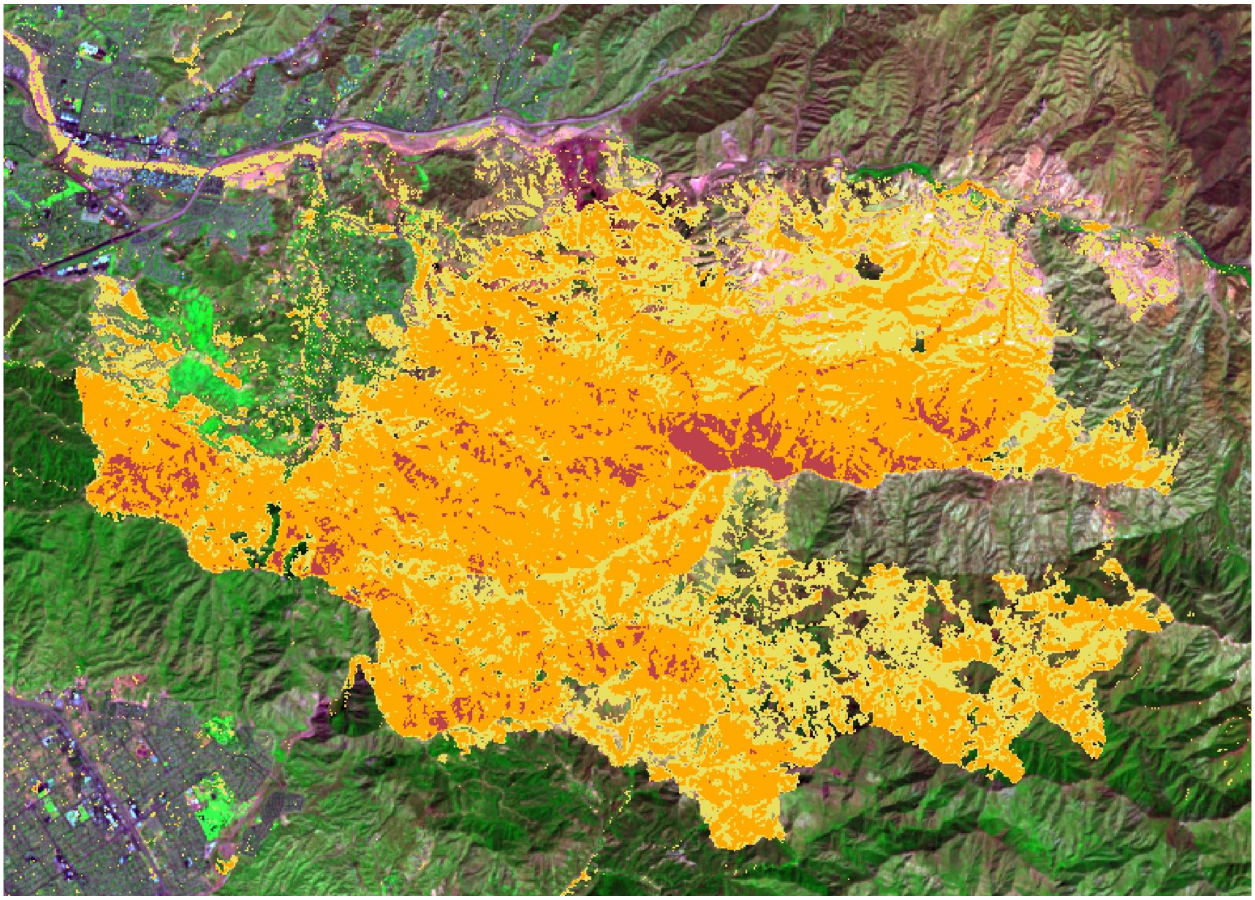
8. Lastly, you will convert this continuous output into severity categories.
    a. In the Geoprocessing Pane, search for "Reclassify".
    b. Select the Reclassify tool (you can use the Spatial Analyst or 3D Analyst version; they are the same).
    c. Set the Input raster to your output dNBR layer.
    d. Make sure Reclass field is set to VALUE.
    e. Click the Classify button. In the pop-up window, change the number of classes to 4. Change the upper value options to reflect the values in Table 2. Set the last break to a large number (I used 300) so that all values are captured in the provided ranges.
    f. Click OK in the Classify window.
    g. In the Reclassify tool window, name the output "dnbr_class". Click Run to execute the tool.







9. Change the colors of the reclassified result. This can be done by selecting the color in the Contents Pane and selecting a new color. The raster codes are as follows: 1 = "Not Burned", 2 = "Low Severity", 3 = "Moderate Severity", and 4 = "High Severity". You can set the color for 1 or "Not Burned" to No color so that it is hollow.



Discussion Point 6: What are some sources of false positives (sites that were not burned but were suggested to be burned)?

Discussion Point 7: It is generally suggested to use near anniversary date images, or images collected around the same time of year, to calculate dNBR. Why is using images that are not near anniversary dates an issue?

Discussion Point 8: What are some issues that could make the operational use of this process for mapping and monitoring fires complicated?