Exercise 1: Change Detection with Visual Inspection and Image Subtraction

Objectives

- Identify appropriate images for detecting change
- Identify change visually using a multi-band approach
- Create a multi-temporal transform and image subtraction to highlight image differences
- Apply a color scheme to visually interpret image change

Overview of Topics

- Examine image bands and creating multi-band images
- Visualize change in images from two dates
- Transform images from two dates using the Normalized Burn Ratio (NBR)
- Calculate a differenced NBR image to identify changes in the vegetation over the same region across two dates

Tools Needed

- QGIS 3.2 for Windows and Mac

Associated Data

- Landsat 8 Surface Reflectance image of Tanzania (2016)
- Landsat 5 Surface Reflectance image of Tanzania (1993)

All associated data must be downloaded from the ARSET website here:
https://arset.gsfc.nasa.gov/land/webinars/adv-change18

Introduction

For this exercise we will examine vegetation changes in Tanzania from 1993 to 2016 using visual investigation and image subtraction techniques. We will use Landsat data from these two years. For the first image in 1993, we will use data from Landsat 5, and the 2016 imagery will be from Landsat 8.

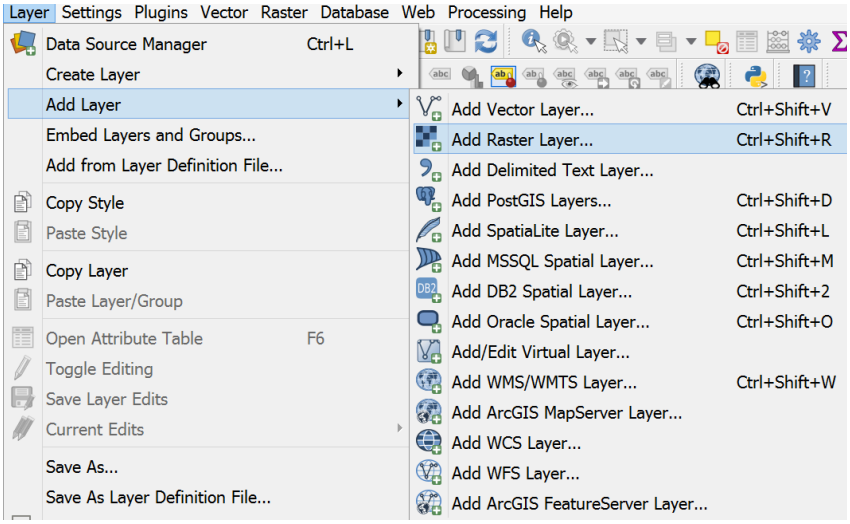
Remember the Landsat data naming convention:

LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CC_TX_pp_BAND

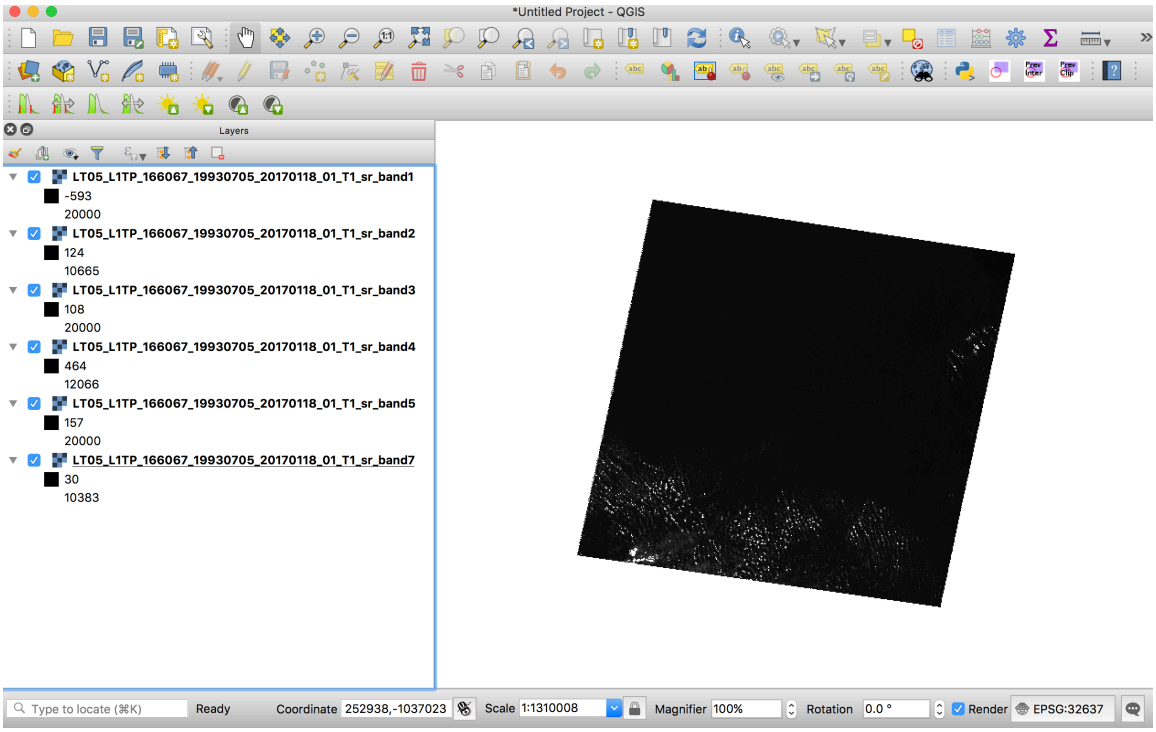
L = Landsat
X = Sensor ("C" = OLI/TIRS combined, "O" = OLI-only, "T" = TIRS-only, "E" = EMT+, "TM" = TM, "M" = MSS)
SS = Satellite ("07" = Landsat 7, "08" = Landsat 8)
LLLL = Processing correlation level *L1TP/L1GT/L1GS)
PPP = WRS path
RRR = WRS row
YYYYMMDD = Acquisition year (YYYY)/Month(MM)/Day(DD)
yyyymmdd = Processing year (yyyy)/Month(mm)/Day(dd)
CC = Collection number (01,02,…)
TX = Collection Category ("RT" = Real-Time, "T1" = Tier1, "T2" = Tier 2)
pp = Product Type (sr = surface reflectance)
BB = Band Number (B1 = band 1, etc.)

Part 1: Imagery Investigation

1. Download the imagery for this exercise here:
    a. Save to an Exercise1 folder you create on your local computer
2. Open QGIS
3. On the top panel click on **Layer > Add Layer > Add Raster Layer**



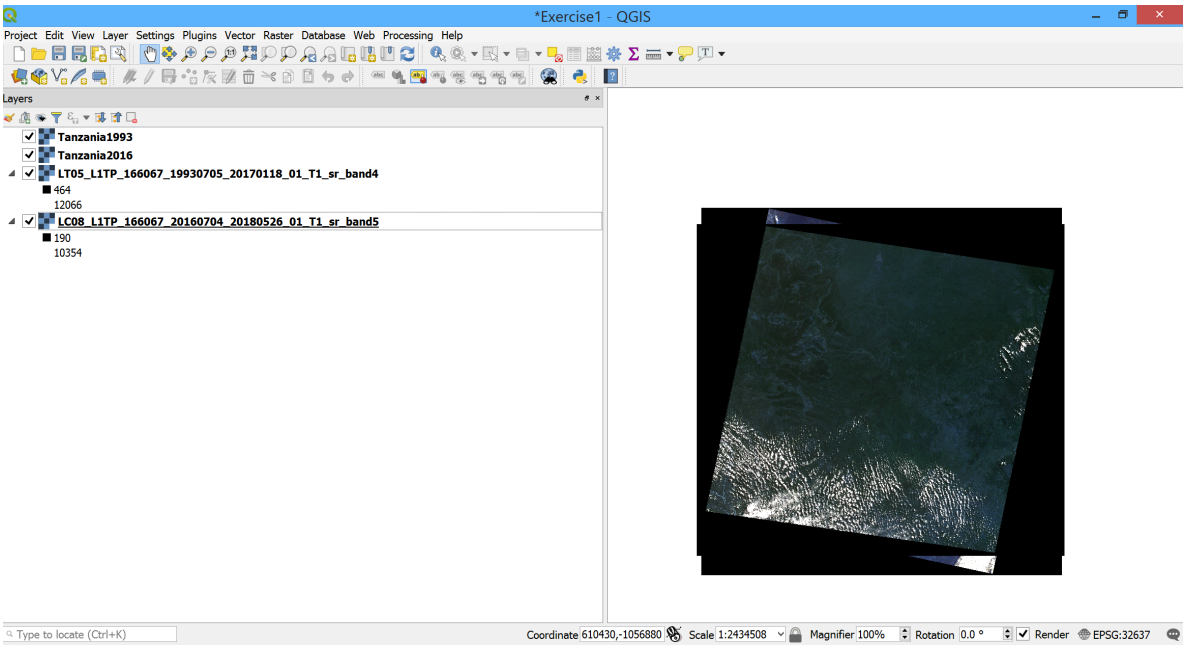
4. Navigate to your **Exercise1** folder and add bands 1-5 and band 7 for the 1993 image. Select each band, click **Add** > **OK** > **Close**. You may need to reorder the bands to ensure they are listed in the **Layers** panel in order.



5. Click on **Raster > Miscellaneous > Merge** to stack the bands together into one image
    a. Click on the … next to **Input Layers** and click on **Select all** to select each band. Click **OK**.
    b. Select the **Place each input file into a separate band** button
    c. Keep the **Output data type** as the **Float32** default
    d. Click on the … next to **Merged** and select **Save to File**. Save the new file as **Tanzania1993.tif** in your **Exercise1** folder.
    e. Click on **Run in Background**
    f. Once the processing is complete, click **Close**
6. Repeat steps 4 and 5 for the 2016 image. Navigate to your **Exercise 1** folder and add bands 1-7 for the 2016 image. Select each band, click **Add** > **OK** > **Close**. You may need to reorder the bands to ensure they are listed in the **Layers** panel in order.
7. Click on **Raster > Miscellaneous > Merge** to stack the bands together into one image
    a. Click on the … next to **Input Layers** and click on each band from the 2016 image. Click **OK**.
    b. Select the **Place each input file into a separate band** button
    c. Keep the **Output data type** as the **Float32** default
    d. Click on the … next to **Merged** and select **Save to File**. Save the new file as **Tanzania2016.tif** in your **Exercise1** folder.
    e. Click on **Run in Background**
    f. Once the processing is complete, click **Close**
8. Click on the **Save Project As**  icon to save your project as **Exercise1.qgz**
9. Remove all the images, including the new "merged" images except for **Band 4** of the original 1993 image and **Band 5** of the original 2016 image
    a. You can remove multiple images by clicking on them in the **Layers Panel** and right click and select **Remove Layer**
10. Click on **Layer > Add Layer > Add Raster Layer**. Select the **Tanzania1993.tif** and the **Tanzania2016.tif** and add them to your project. When you merge the images QGIS will create a temporary file called **Merged** in your layers panel, and each merged image will have the same name. By removing the temporary

merged images and adding in the images you created, this will save confusion in the next steps.

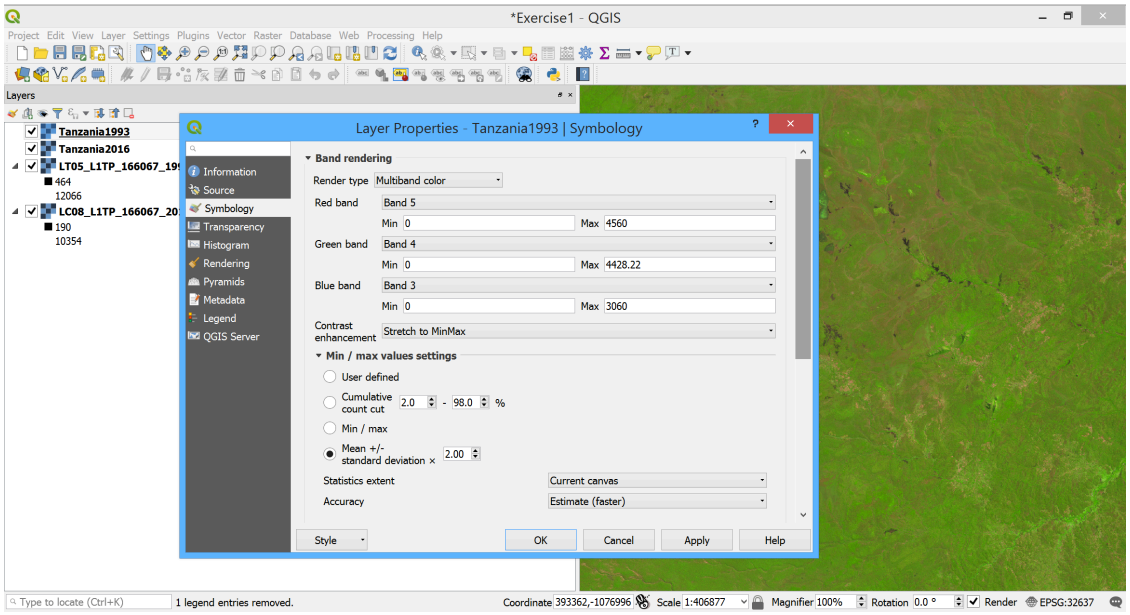
11. Move the **Tanzania1993** image on top of the **Tanzania2016** image in the **Layers Panel**



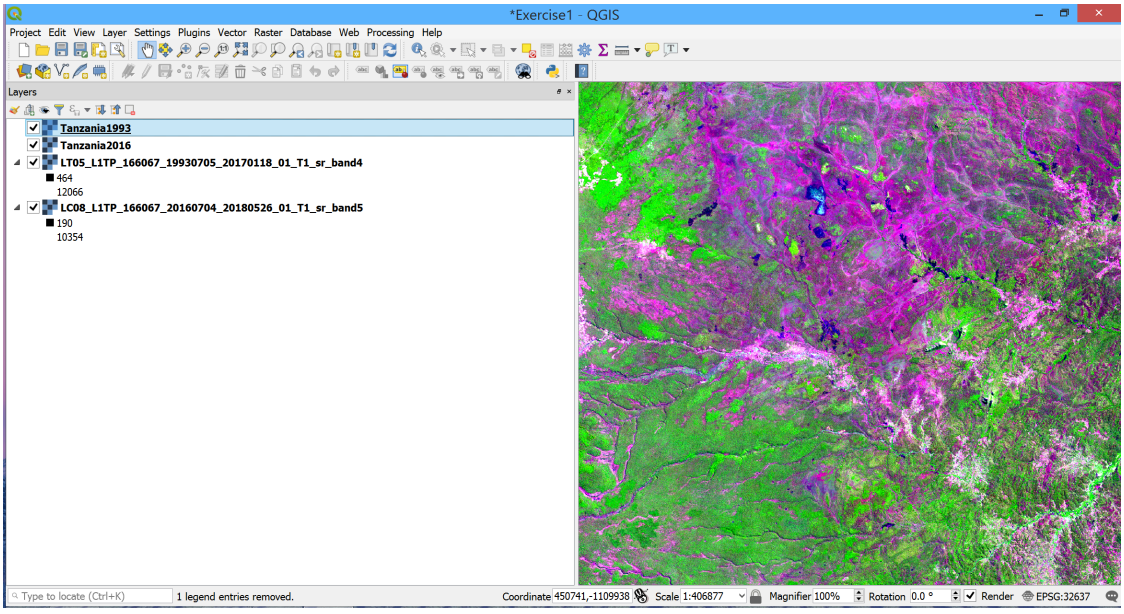
Next, we will change the colors of the imagery to make it more visually appealing.

12. For the **Tanzania1993** image, zoom into an area without clouds
13. Right click on the **Tanzania1993** image in the Layers Panel and click on **Properties**. A window will pop up and you should be taken directly to the Symbology tab.
    a. Leave the **Render type** as the default **Multiband color**
    b. Change the **Red band** to **Band 5**
    c. Change the **Green band** to **Band 4**
    d. Change the **Blue band** to **Band 3**
    e. Click **Apply**

You should notice that the color in the image changes to show mostly green. Do not close the Layer Properties window yet or change the zoom level.



14. Click on the drop down arrow next to **Min/max value settings**
15. Turn on the **Mean +/- standard deviation** and ensure the value is set to 2.00 (this should be the default)
16. In the drop down next to **Statistics extent** choose **Current canvas**
    a. Click **Apply**, then **OK**



17. Repeat steps 12-16 for the **Tanzania2016** image. All steps will be the same, except for the color combinations. Use:
    a. Change the **Red band** to **Band 6**
    b. Change the **Green band** to **Band 5**
    c. Change the **Blue band** to **Band 4**

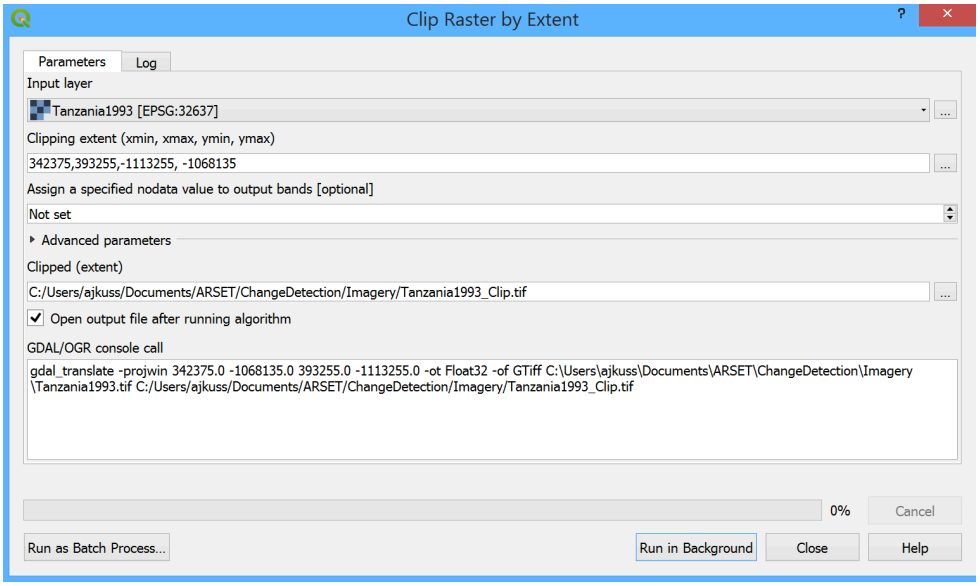
Remember the differences in the bands for each Landsat sensor. Here is a nice review: https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

18. In the **Layers Panel**, right click on the 1993 image and click on **Zoom to Layer**. Turn the **1993** and **2016** images on and off in the **Layers Panel** to double check to ensure the color combinations are correct and start to visually examine some of the differences you see in each image.

When examining each image, you should see some differences in the vegetation (bright green) from 1993 to 2016.

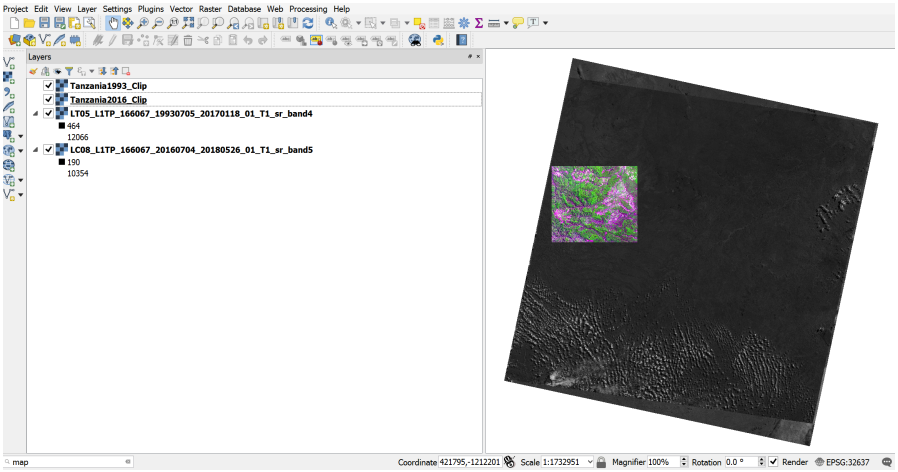
Now we are going to clip the images to remove the clouds you see in the southern portion of the 1993 image and along the eastern and western edges of the 2016 image.

19. Along the top panel, select **Raster > Extraction > Clip Raster by Extent**
    a. Input Layer: Tanzania1993
    b. Clipping extent: 342375, 393255, -1113255, -1068135
    c. Click on the  next to **Clipped (extent)**, select **Save to file**, and save to your Exercise1 folder as **Tanzania1993_Clip.tif**. Click **Save.**
    d. Click on **Run in Background**
    e. Click **Close**



20. Go back to your map. In the **Layers Panel** turn off all layers except for the new Clipped (extent) layer. You will notice that we have clipped a small area of the 1993 image.
21. Repeat step 19 for the 2016 image, this time using the new clipped 1993 image extent as your extent. Along the top panel, select **Raster > Extraction > Clip Raster by Extent**
    a. Input Layer: Tanzania2016
    b. Clipping extent: Click on the ... next to **Clipping extent** and select **Use layer/canvas extent**. In the pop-up window under **Use extent from** select Clipped (extent). Click **OK**.
    c. Click on the ... next to **Clipped (extent)** and select **Save to file** and save to your Exercise1 folder as **Tanzania2016_Clip.tif** and click **Save**.
    d. Click on **Run in Background**.
    e. Click Close
22. You will now notice two clipped (extent) temporary images in the **Layers Panel**. Remove both of the **clipped (extent)** temporary images and the **Tanzania1993** and **Tanzania2016** images by right clicking on them and selecting **Remove Layer**.
23. Click on the **Add Raster** icon or go to **Layer > Add Layer > Add Raster Layer** and add the **Tanzania1993_Clip.tif** and the **Tanzania2016_Clip.tif**. Ensure that the 1993 image is on top of the 2016 image in the **Layers Panel**.

24. Now you will need to recolor the images like we did in steps 13-16. Right click on the **Tanzania1993_Clip** image in the Layers Panel and click on **Properties**. A window will pop up and you should be taken directly to the **Symbology** tab.
    a. Leave the **Render type** as the default **Multiband color**.
    b. Change the **Red band** to **Band 5**
    c. Change the **Green band** to **Band 4**
    d. Change the **Blue band** to **Band 3**
    e. Click **Apply**
25. Click on the drop down arrow next to **Min/max value settings**
26. Turn on the **Mean +/- standard deviation** and ensure the value is set to 2.00 (this should be the default)
27. In the drop down next to **Statistics extent** choose **Whole Raster** (this is OK now, since we have already clipped out the really high reflectance values from the clouds)
    a. Click **Apply**, then **OK**
28. Recolor the clipped 2016 image. Remember the difference in the band combinations.
    a. Change the **Red band** to **Band 6**
    b. Change the **Green band** to **Band 5**
    c. Change the **Blue band** to **Band 4**
29. Repeat steps 25-27 to ensure the image statistics are displayed in the same manner
30. Remember to always **Save** your map along the way

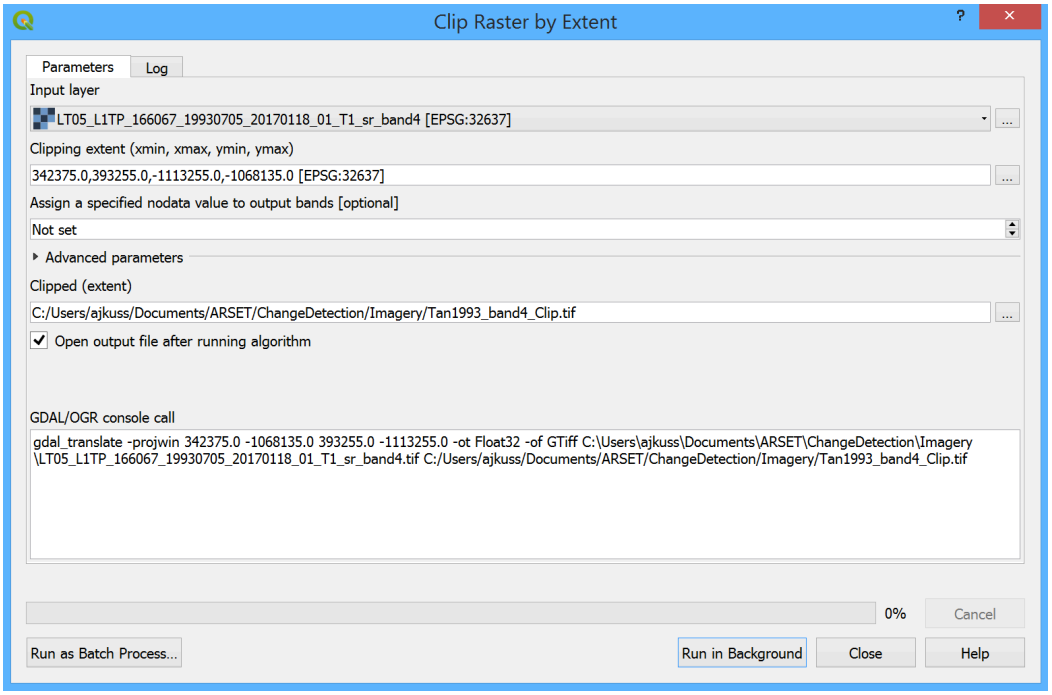


Part 2: Visualizing Change

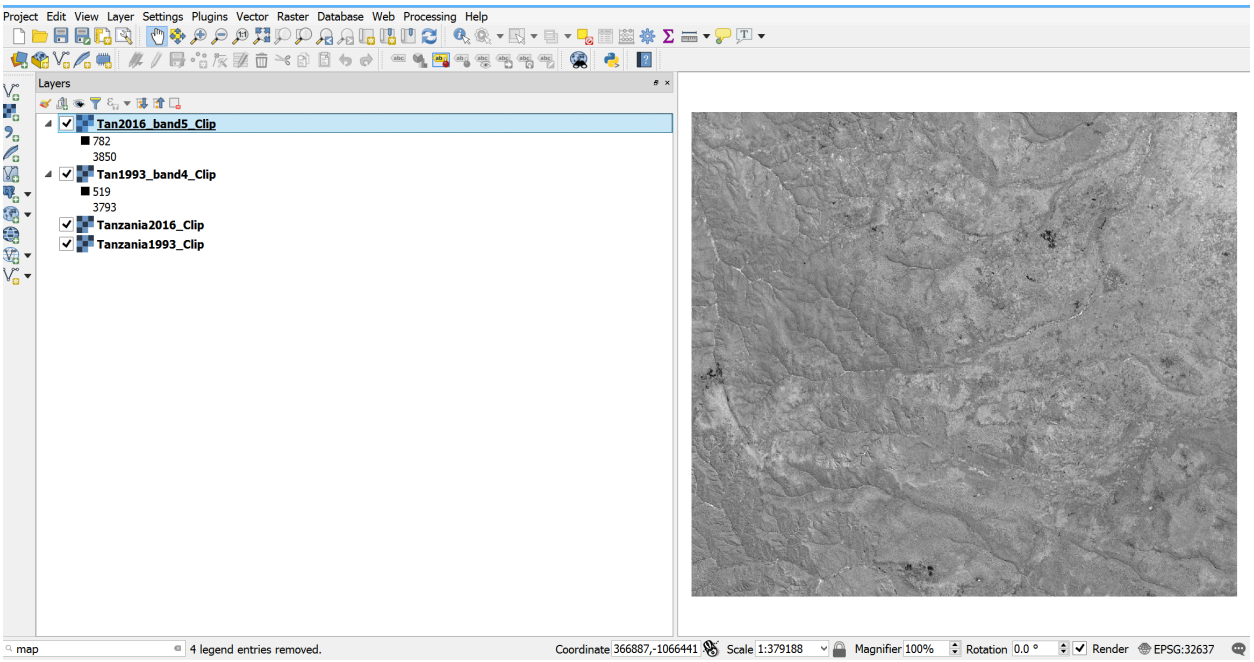
Now we will do a simple visualization of change using the near-infrared (NIR) band of each date. Remember that the Landsat 5 NIR band is band 4 and the Landsat 8 NIR band is band 5. You should still have the Band 4 layer of the 1993 image and the Band 5 layer of the 2016 image in the **Layers Panel**.

We will begin by combining the NIR bands of the two images to visualize change. We will first clip the Band 5 and Band 4 images to the extent of the other images.

1. Along the top panel, select **Raster > Extraction > Clip Raster by Extent**
    a. Input Layer: LC05_L1TP_166067_19930705_20170118_01_T1_sr_band4
    b. Clipping extent: Click on the … next to **Clipping extent** and select **Use layer/canvas extent**. In the pop-up window under **Use extent from** select **Tanzania1993_Clip** and click **OK**.
    c. Click on the … next to **Clipped (extent)** and select **Save to file** and save to your Exercise1 folder as **Tan1993_band4_Clip.tif** and click **Save**
    d. Click on **Run in Background**
    e. Click **Close**

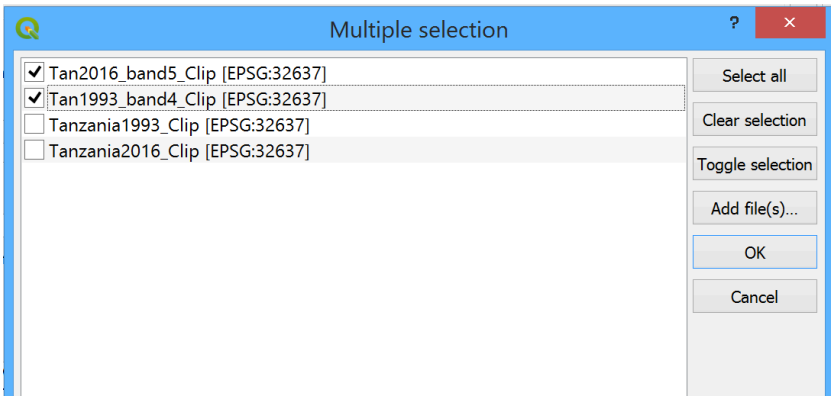


2. Repeat for the Band 5 2016 image. Select **Raster > Extraction > Clip Raster by Extent**.
    a. Input Layer: LC08_L1TP_166067_20160704_20180526_01_T1_sr_band5
    b. Clipping extent: Click on the … next to **Clipping extent** and select **Use layer/canvas extent**. In the pop-up window under **Use extent from** select **Tanzania1993_Clip** and click **OK**.
    c. Click on the … next to **Clipped (extent)** and select **Save to file** and save to your Exercise1 folder as **Tan2016_band5_Clip.tif** and click **Save**.
    d. Click on **Run in Background**
    e. Click **Close**
3. Remove the temporary **Clipped (extent)** images and the original **Band 4** and **Band 5** images from the **Layers Panel**
4. Add the **Tan1993_band4_Clip.tif** and the **Tan2016_band5_Clip.tif** to the map. Ensure the layers are organized as outlined in the image below.



Now, we will combine the two NIR images (Band 5 for the 2016 image and Band 4 for the 1993 image) and examine changes in the vegetation from 1993 to 2016.

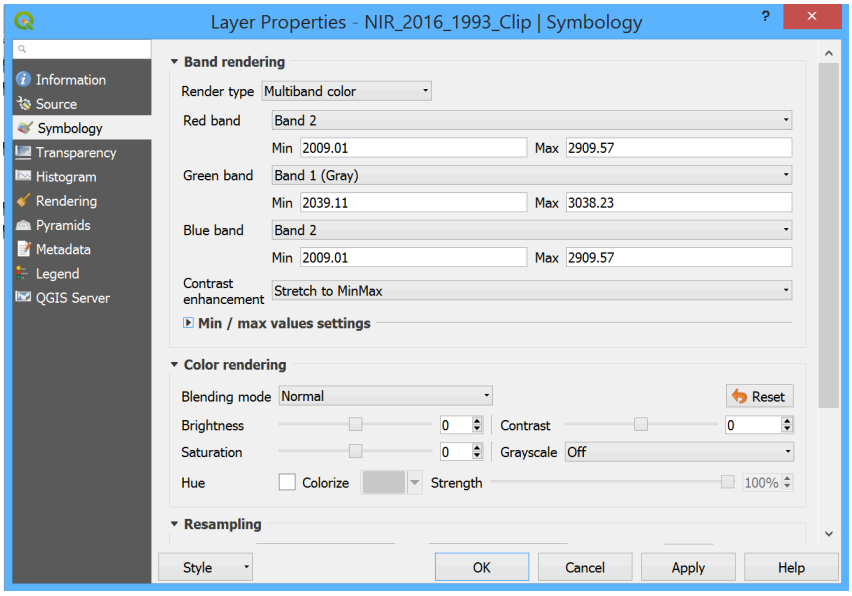
5. Along the top panel, select **Raster > Miscellaneous > Merge**
    a. Click on the ... next to **Input Layers** and select **Tan2016_band5_Clip** and **Tan1993_band4_Clip** then click **OK**. Ensure that Tan2016 is listed first (this will become band 1 in the new image) and that Tan1993 is listed second (this will become band 2 in the new image). If they are not in this order, you can click on the 2016 image and drag it to the top in the **Multiple selection** window.



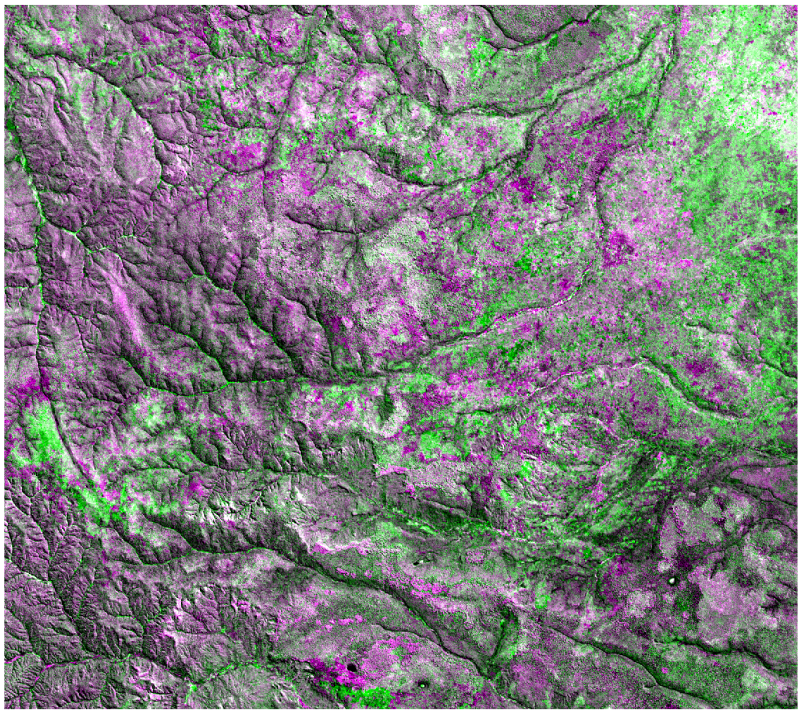
   b. Select the **Place each input file into a separate band** button
   c. Keep the **Output data type** as the **Float32** default
   d. Click on the  next to **Merged** and select **Save to File**. Save the new file as **NIR_2016_1993_Clip.tif** in your **Exercise1** folder.
   e. Click on **Run in Background**
   f. Once the processing is complete, click **Close**
6. Remove the temporary **Merged** layer, the **Tan2016_band5_Clip** layer, and the **Tan1993_band4_Clip** layers from your map. Add the **NIR_2016_1993_Clip.tif** to the map using the **Add Raster** function.

Now we will recolor the NIR image to show purple indicating decreases in vegetation, green indicating increases in vegetation, and grey indicating no change.

7. Right click on the **NIR_2016_1993_Clip** image select **Properties** and go to the **Symbology** tab.
   a. Render Type: Multiband color (default)
   b. Red Band: Band 2 (this is the 1993 NIR band)
   c. Green Band: Band 1 (this is the 2016 NIR band)
   d. Blue Band: Band 2
   e. Contrast enhancement: Stretch to MinMax (default)
   f. Min/max values settings: Mean +/- standard deviation 2
   g. Click **Apply**
8. Note the **Min** and **Max** values may not show up in the white bars under the Blue band. If they don't then type in the same value that you see for the Red band/Band 2 after you click **Apply** from Step 7.
9. Click **Apply**, then **OK**



You can see a lot of purple indicating a decrease in vegetation but you can also see a lot of green indicating increased vegetation. Zoom in on a couple areas that are green and click the images on and off to see the increased vegetation between 1993 and 2016. Do the same for a few purple areas to see the decreased vegetation.



Part 3: Single-Date Transformations

Another method to help changes visibly stand out is the multi-temporal transformation. There are many types of transformations, so you will first need to decide on what type of transformation you would like to perform on your imagery. Each transformation has its own advantage. By creating a transformation, you are leveraging multiple bands of information to highlight specific information that you are looking for.

The table below describes the purposes of different transformations, as well as their formulas. These are some of the common transformations, but there are many more that might be useful. For example, if your area of interest has less vegetation and a lot of soil, you may want to consider a Soil Adjusted Vegetation Index (SAVI).

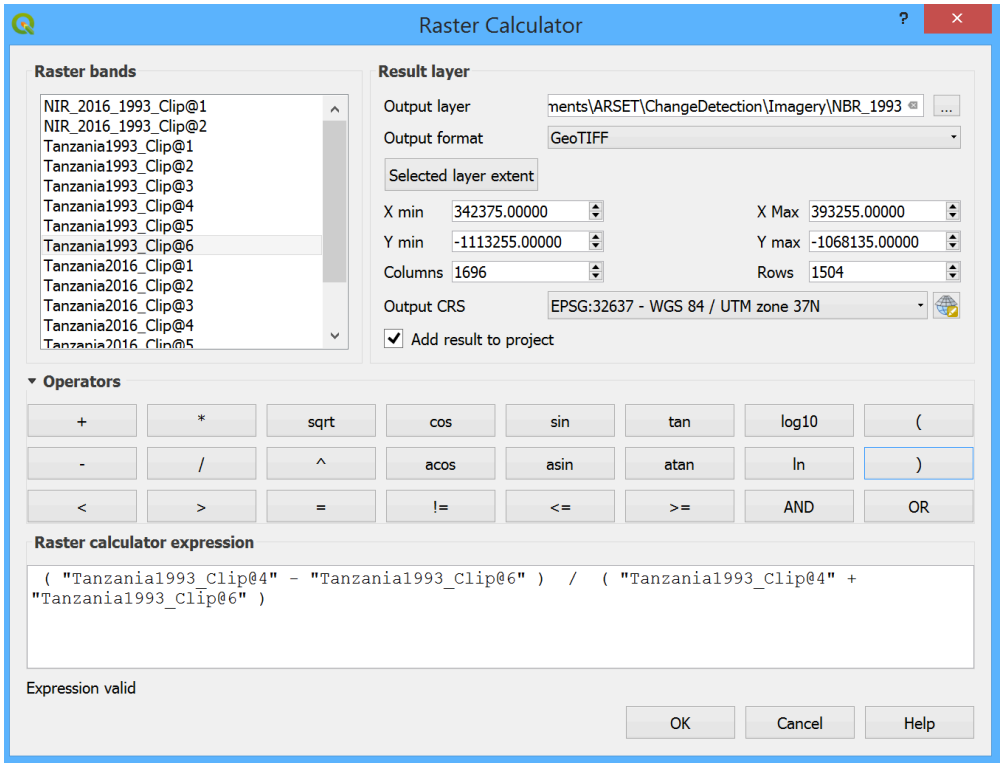
Transform	Formula	Purpose
Normalized Difference Vegetation Index (NDVI)	(NIR-RED)/(NIR+RED)	Differentiates between vegetated and non-vegetated land. Ranges from -1 to 1
Enhanced Vegetation Index (EVI)	2.5*(NIR-RED)/NIR+6.0*RED-7.5*BLUE+1.0)	Alternative to NDVI for highlighting vegetation. It is sensitive to areas with high biomass
Normalized Burn Ratio (NBR)	(NIR-SWIR2)/(NIR+SWIR2)	Highlight burn scars and severity. Works well for other types of change as well.

To highlight a transformation method, we will use the Normalized Burn Ratio. We will apply this transformation to the images for each date, then compare the differences in these images.

1. Move the **NIR_2016_1993_Clip** image to the bottom of your Layers Panel. You can do this by selecting it and dragging it below the other two layers.
2. First we will apply the NBR to the **Tanzania1993_Clip** image. Along the top panel select **Raster > Raster Calculator**
3. Use the NBR equation within the Raster calculator by double clicking on the appropriate band names in the Raster Bands panel. This will automatically add them to the **Raster calculator expression** box. The equation should look like this:

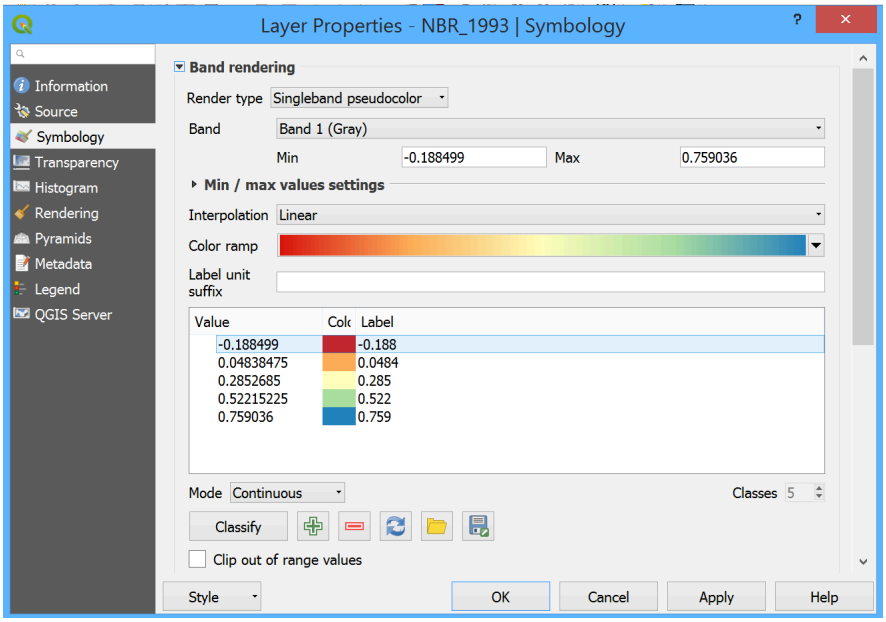
("Tanzania_1993_clip@4"-"Tanzania_1993_clip@6")/("Tanzania_1993_clip@4" + "Tanzania_1993_clip@6")

4. Click on the ... next to **Output Layer** and navigate to your Exercise1 folder and save the new image as **NBR_1993.tif**
5. Click **OK**



Now we will apply a stretch to the new NBR image.

6. Right click on your **NBR_1993 image** and go to **Properties** and the **Symbology** tab.
    a. Render Type: Singleband Pseudocolor
    b. Color Ramp: Spectral



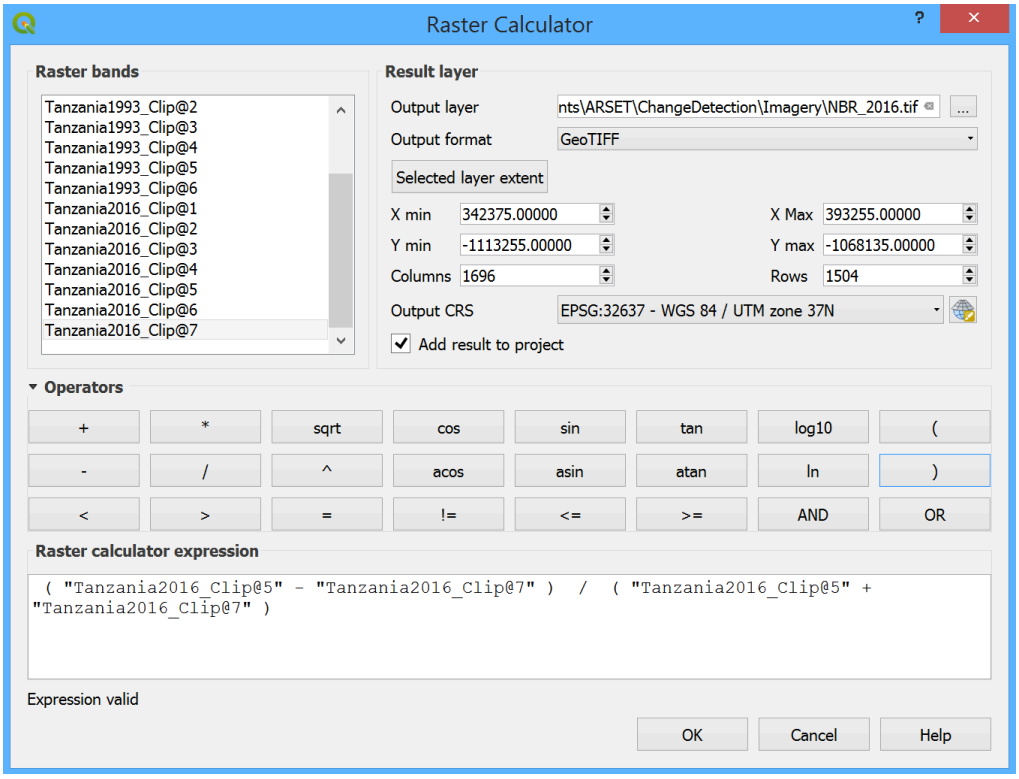
7. Click **Apply,** then **OK**
8. Turn off all layers except your **NBR_1993** image and your **Tanzania1993_Clip** image. Now click the NBR layer on and off, and continue to switch back between those two layers.

Note how the transformed values and colors relate to features in the image. Red and yellow colors indicate little to no vegetation, while green to blue colors indicate higher amounts of vegetation.

1. Now we will repeat steps 2-8 for the 2016 image. However, remember that the band combinations will be different for the NBR calculation (band 5 (NIR) and band 7 (SWIR2)). Along the top panel select **Raster > Raster Calculator**
2. Use the NBR equation within Raster calculator by double clicking on the appropriate band names in the Raster Bands panel. The equation should look like this:

("Tanzania_2016_clip@5"-"Tanzania_2016_clip@7")/("Tanzania_2016_clip@5" + "Tanzania_2016_clip@7")

3. Click on the ... next to **Output Layer** and navigate to your Exercise1 folder and save the new image as NBR_2016.tif
4. Click **OK**



5. Remember to **Save** your map along the way
6. Now we will copy the style from the NBR_1993 image to the NBR_2016 image. Right click on the NBR_1993 image and click on **Styles > Copy Style**.
7. Click on the NBR_2016 image and click on **Styles > Paste Style**
8. Now click the NBR_2016 and NBR_1993 layers on and off, and continue to switch back between those two layers to examine the differences

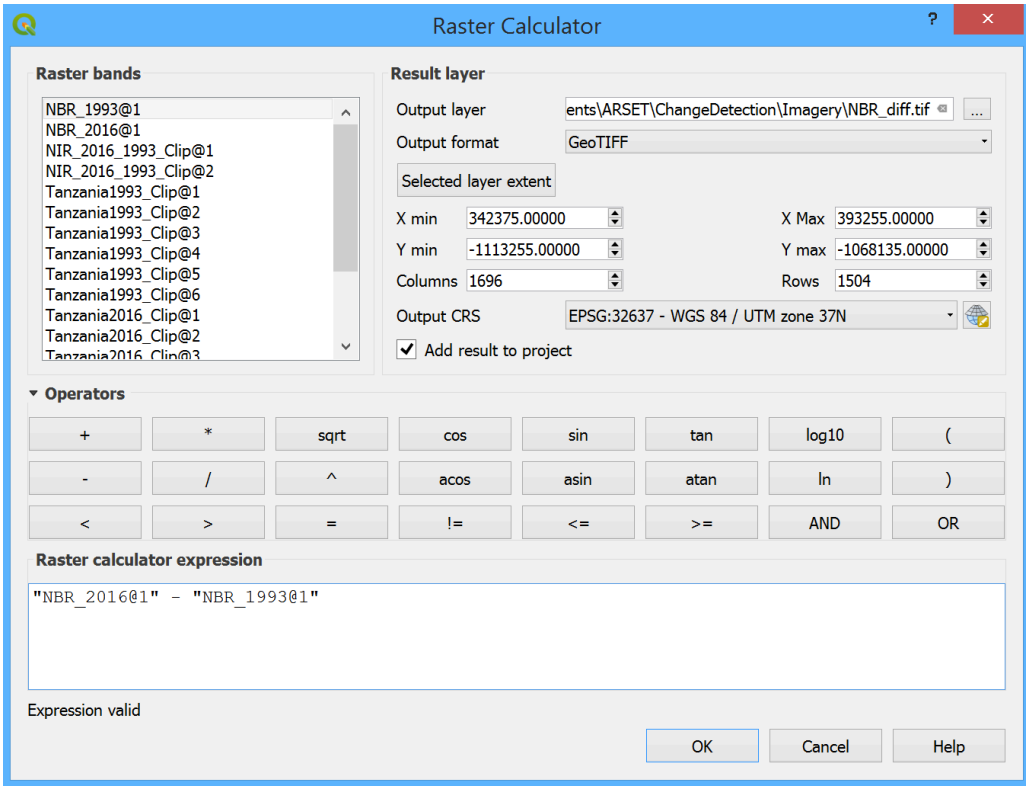
Part 4: Multi-Temporal Transformations

Now that you have two single date transformations, you can create a layer that shows the difference between the two dates by subtracting one from the other.

1. Along the top panel, click on **Raster > Raster Calculator**
2. In the **Raster calculator expression** box, write an expression that subtracts the first NBR image (NBR_1993) from the second NBR image (NBR_2016). The equation should look like this:

"NBR_2016@1"-"NBR_1993@1"

3. Click on the ... next to **Output Layer** and navigate to your Exercise1 folder and save the new image as NBR_Diff.tif
4. Click **OK**



5. Again, apply a coloration to your new image. Right click on the NBR_diff image, click on **Properties** and go to the **Symbology** tab.
    a. Render Type: Singleband Pseudocolor
    b. Color Ramp: Spectral
6. Click **Apply,** then **OK**
7. To make the colors more meaningful, we can change the values assigned to each color. Right click on the NBR_diff image, click on **Properties** and go to the **Histogram** tab.
8. Click on **Compute Histogram**

Most of the values are around 0. The extreme values are below -0.5 and above 0.5. This means good breakpoints are -0.5, -0.25, 0, 0.25, 0.5.

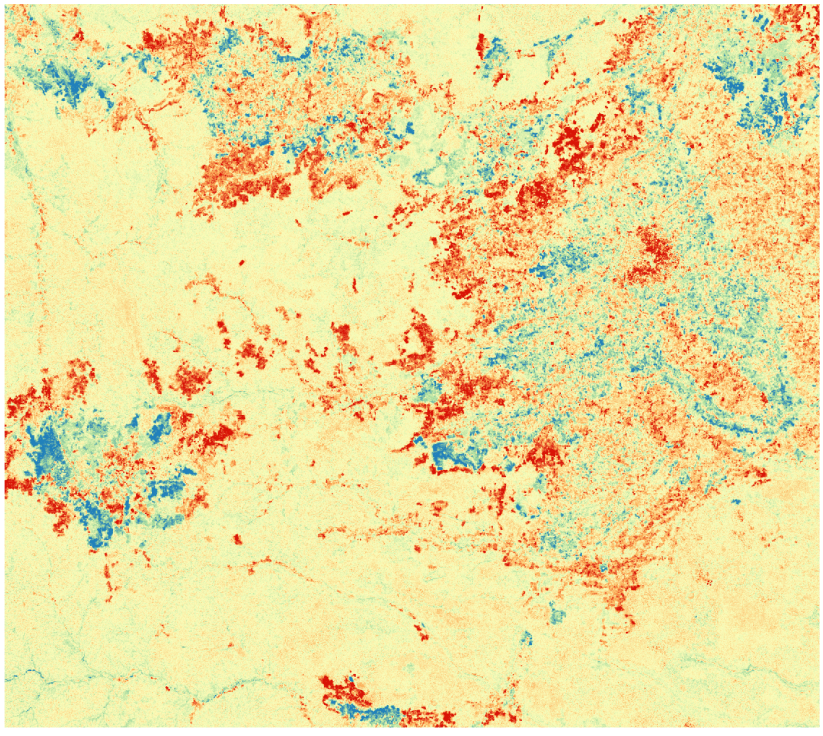
9. Click on the **Symbology** tab. Double click on the first number just below **Value** to the left of the red color and input -0.5. Copy the -0.5 under the **Value** column and input it in the same row under the **Label** column.
10. Repeat step 9 for each of the consecutive values that we decided would be good breakpoints (-0.25, 0, 0.25, 0.5).

Value	Color	Label
-0.5		-0.5
-0.25		-0.25
0		0
0.25		0.25
0.5		0.5

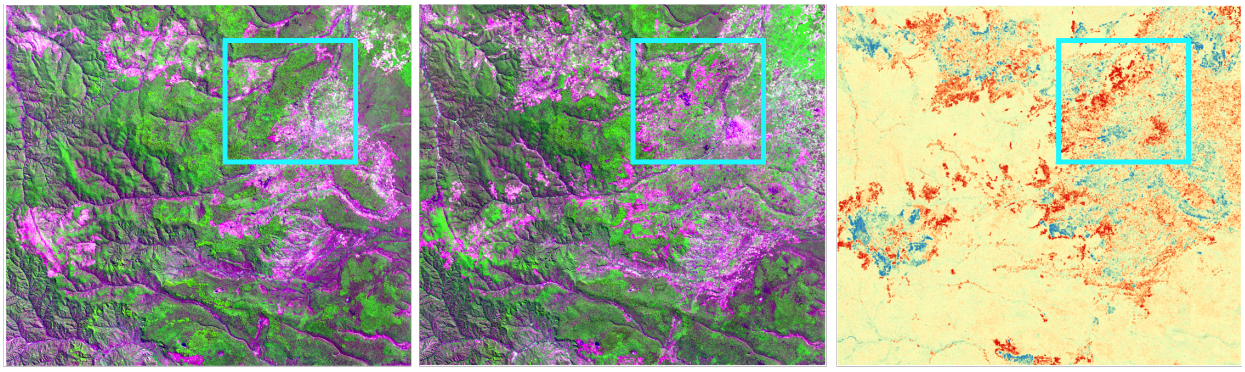
11. Click **Apply**, then **OK**

The large positive (blue) and large negative (red) values indicate change in the image, while the values close to 0 represent little to no change.

Compare this image with the 1993 and 2016 clipped Landsat images to confirm the changes you are seeing. What types of patterns do you observe between these images?



For example, let's examine one region in the northwestern portion of our images.



1993 2016 dNBR (2016-1993)

The area in the blue box is heavily vegetated in 1993, as indicated by the dark green. In the 2016 image it does not appear to be highly vegetated, but it looks more like bare ground. In the differenced NBR image, where we subtracted the 1993 NBR values from the 2016 NBR values, you can see negative values in red. This may indicate that a fire burned in this area between 1993 and 2016.

Additionally, in the southwestern portion of the dNBR image (far left) image you can see an area indicated in dark blue. In the 1993 image this region appears purple, and in the 2016 image this region appears green. This could also indicate vegetation regrowth from 1993 to 2016.

If you would like to see what the area looks like using Google Earth, open Google Earth and type Liwale, Tanzania in the Search box.

Conclusion

In this exercise you examined two methods for simple change detection:

1. visualizing change, and
2. using transformations to indicate change.

These are good methods to begin understanding change and why it is happening in a specific region. For a more in-depth analysis, you could explore more years to see the year of a forest disturbance or use different transformations to understand drought conditions over time.