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EXERCISE 3
Image enhancements in ArcGIS

Introduction

Creating indices and image transformations can help simplify data, minimize noise, and improve our ability to detect specific types of landscape changes. There are a number of existing indices and image transformations, and while there can be some overlap in the information that they present, each has been developed with a unique purpose in mind. In this exercise, we will use the Landsat imagery from the previous exercise to conduct an exploratory analysis of image enhancements in northern Arizona. These enhancements will help us determine which of the image enhancements, if any, would be most useful for a change detection study of the area.

Objectives

- Review Landsat images
- Create NDVI and NBR images
- Create Tasseled Cap transformation images
- Explore and interpret different image enhancement

Required Data

- **Landsat image pair: NorthernAZ_2002_2002_152_181_Composite.tif and NorthernAZ_2011_2011_152_181_Composite.tif –** These images of northern Arizona capture several types of change including vegetation change resulting from wildfire, drought, and human activities. They were created with the EE script used in the previous exercise, but you can also find them included in the course data.

Prerequisites

- You have **ArcGIS 10.x** installed on your machine with the **Spatial Analyst** extension enabled.

Note: It is assumed that you will use the provided course data; you can, however, create image enhancements using any imagery, so long as you are aware of potential differences in band designations between sensors and how to proceed accordingly. Coefficients required to create the Tasseled Cap transformations have only been calibrated for some sensors (e.g., Landsat, SPOT, QuickBird, and WorldView2); if your data comes from another sensor, you will have to investigate whether coefficients have been derived for the Tasseled Cap transformation.

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Part 1: Review Landsat images

In this section, you will open the two Landsat images in ArcGIS, review the imagery, and navigate to the specified subset area before beginning work.

A. Locate the data in your local course directory

1. Navigate to your Download folder and locate the 2002 and 2011 images that you downloaded from your Google Drive. If you were unable to run through the previous exercises, navigate to the course data.
   i. Make sure that the two Landsat images, **NorthernAZ_2002_2002_152_181_Composite.tif** and **NorthernAZ_2011_2011_152_181_Composite.tif**, are present.

B. Open the Landsat image pair in ArcGIS

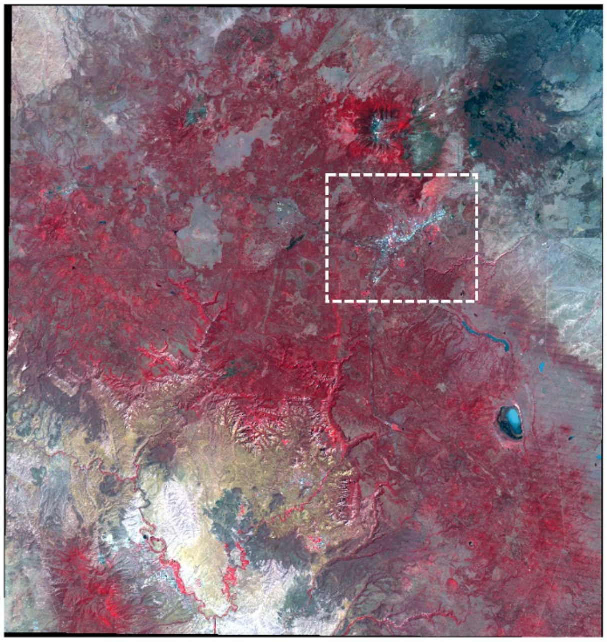
1. Launch ArcGIS by select the Start menu, ArcGIS, and then ArcMap 10.x.
2. Drag the two TIF files from your **Windows Explorer** window into the ArcGIS viewer to add them to your map.
   i. Alternatively, click the **Add Data** button (shown below) and navigate to the files within the Add Data window. Press the **CTRL** key and **select both TIF files**. Click **Add** to add the files to the viewer.

3. If asked if you want to build pyramids for the images, select **Yes**.
4. Adjust the image composites to create color infrared composites. For each image:
   i. Choose **Band 4** for the **red color gun**.
   ii. Choose **Band 3** for the **green color gun**.
   iii. Choose **Band 2** for the **blue color gun**.

C. Inspect the image pair

1. Zoom to the Flagstaff area using the **Zoom In** tool (shown below).
   i. Click the **Zoom In** button.

   ii. Click and drag the mouse to draw a box around the area outlined in the graphic below.



2. Explore the image by clicking on the **Pan** tool (shown below). Click and drag the mouse to navigate to different parts of the image.

3. Open the **Effects** tool bar.
   i. Within the grey toolbar at the top of your ArcGIS window, right-click and select **Effects** to enable the Effects toolbar.

Note: If there is a check mark next to the Effects label, it is already enabled.

4. Turn on the **Swipe** tool (shown below).
   i. Select the Swipe button.
   ii. Hover your mouse over the ArcGIS viewer. You should see a small black triangle instead of your normal mouse cursor.
   iii. Click and drag to swipe between the 2002 and 2011 images.

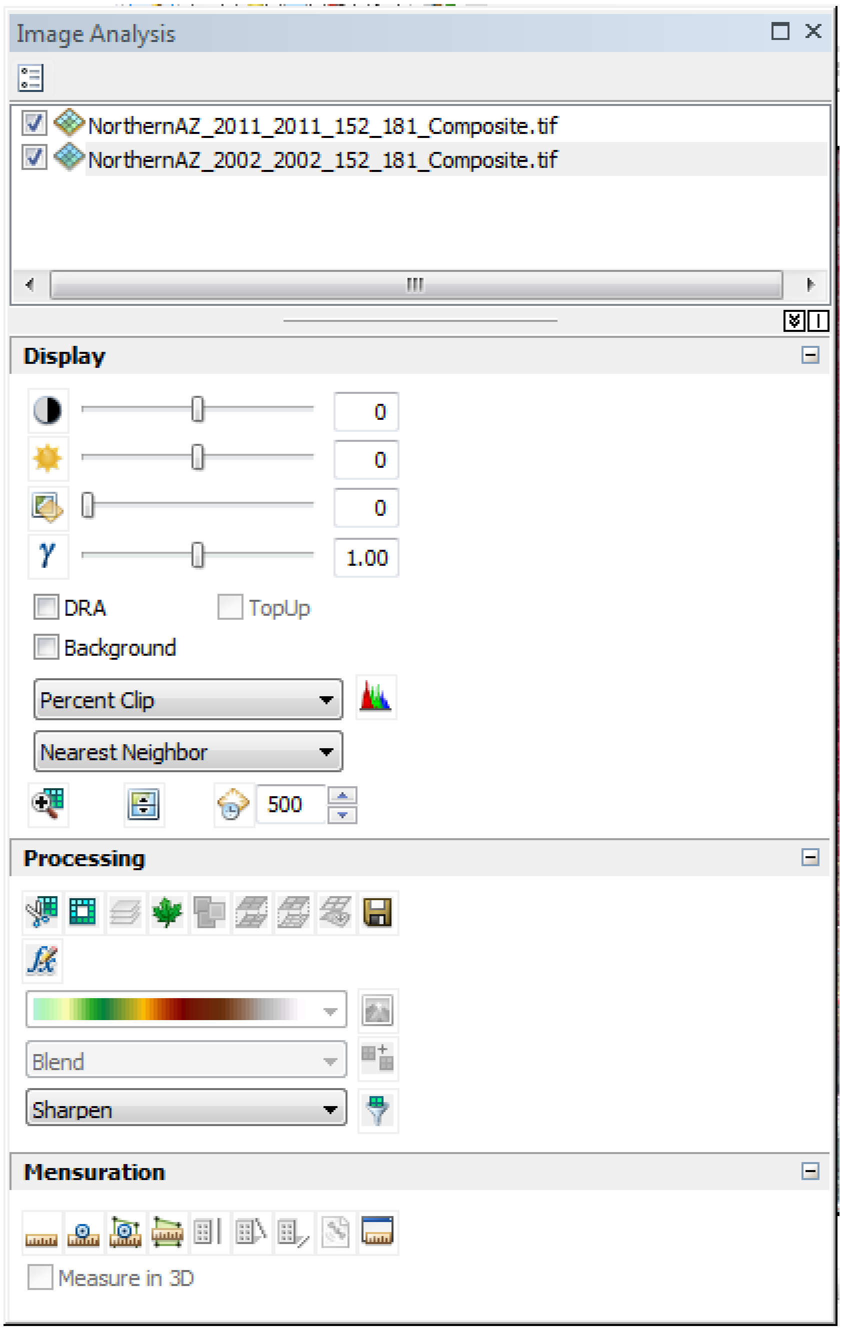
Note: Visually compare the imagery from both points in time. Note landscape features of interest (forests, golf courses, water bodies, urban features, burned areas, et cetera) and how they have or have not undergone change between the two image dates.

Part 2: Create NDVI and NBR images

You will use ArcGIS to create two vegetation indices, Normalized Difference Vegetation Index (NDVI) and Normalized Burn Ratio (NBR).

A. Create NDVI images

1. Open the **Image Analysis** window by selecting the **Windows** menu and then **Image Analysis**.
2. Highlight the 2002 image.



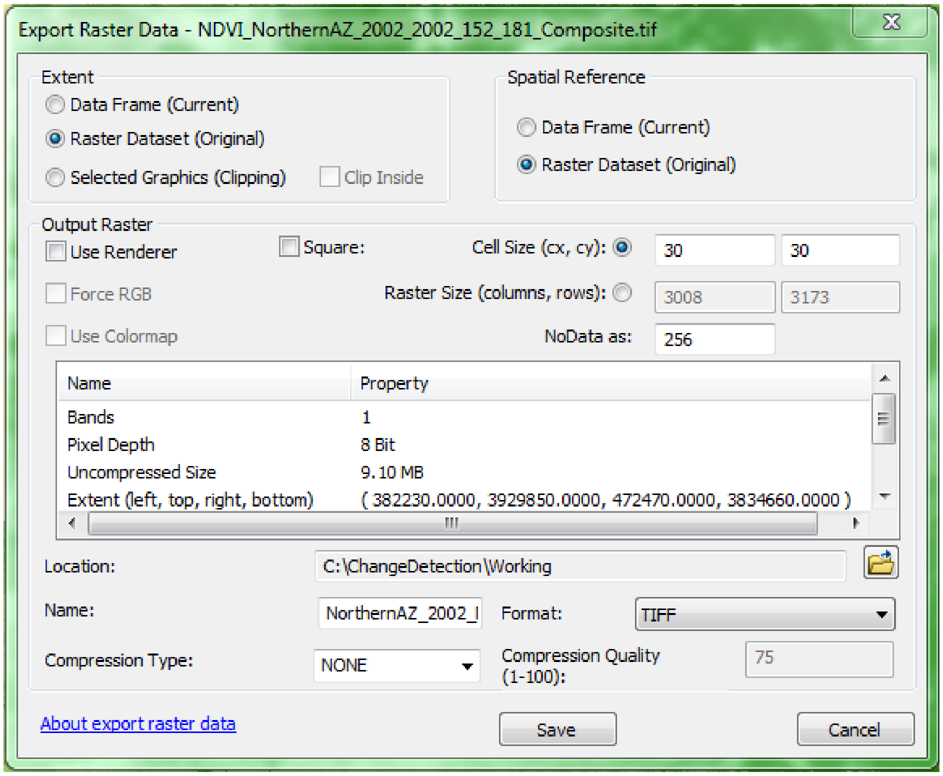
3. Make sure that the correct bands are specified as near infrared and red in the Image Analysis window.
   i. Click on the **Image Analysis Options** button in the upper left corner of the window (shown below).

   ii. Verify that **Red Band** is set to **3** – if it is not, change it.
   iii. Verify that **Infrared Band** is set to **4** – if it is not, change it.
   iv. Click **OK** to close.
4. Click the **NDVI** button (shown below).

5. An NDVI layer will be automatically created and added to your viewer.
6. In the **Image Analysis** window, select the **2011 image** and then the **NDVI** button to create an NDVI layer.
7. Close the Image Analysis window.

> *Note: The Image Analysis window is great for creating on-the-fly layers, but they come with some caveats. The images are not written to file. In order to be able to use them later, we need to export them. The images are also created in a byte format, meaning that they range in value from 0 to 255 instead of the typical scale of -1 to 1 for NDVI images. Because NDVI is a unitless, relative metric, this is okay! However, the values may be a bit unfamiliar and more challenging for someone to interpret.*

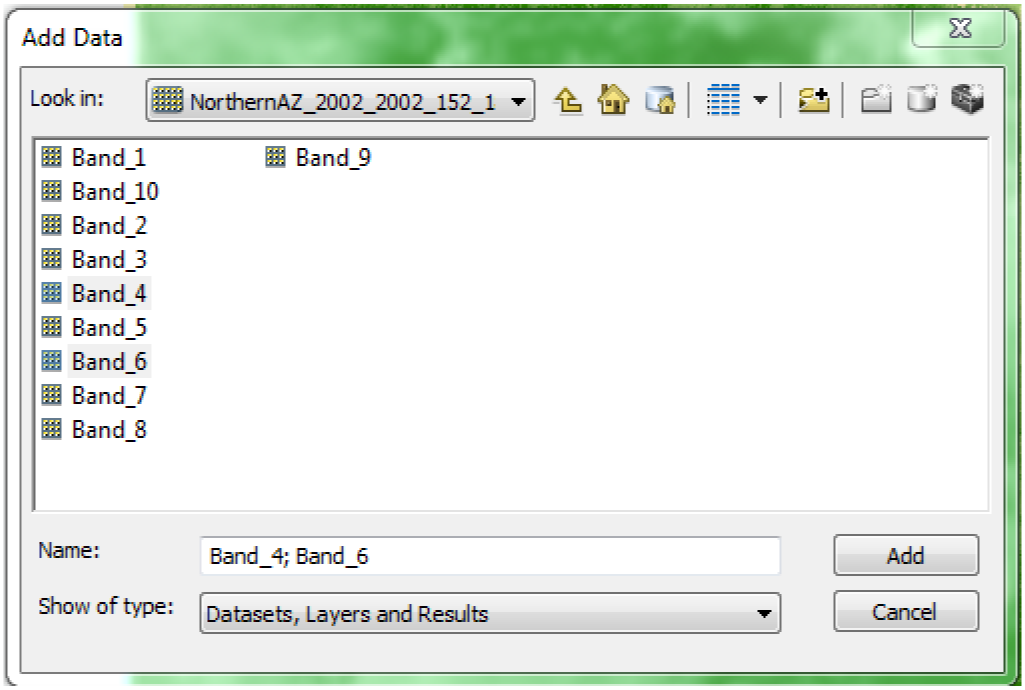
8. Right-click on **NDVI_NorthernAZ_2002_2002_152_181_Composite.tif** and select **Data** and then **Export Data…**
   i. Use the **yellow folder icon** adjacent to the **Location** field to choose the location of your **working folder**
   ii. Specify **NorthernAZ_2002_NDVI.tif** as the **Name**
   iii. From the **Format** dropdown menu, select **TIFF**
   iv. Select **Save**



9. You may receive a message asking if you want to promote pixel depth. Click **Yes**.
10. If asked if you would like to add the output to your map, select **Yes**.
11. Repeat for the **2011** image.

B. Add individual image bands to your viewer

1. Click the **Add data** button and navigate to the location of your two Landsat image composites.
2. Double-click on the **NorthernAZ_2002_2002_152_181_Composite** image. You should now see a list of 10 image bands.
3. Hold down the **CTRL** key and select **Band_4** and **Band_6**, as shown below.



4. Click **Add** to add the bands to your viewer.
5. Repeat **steps 2-4** for the **NorthernAZ_2011_2011_152_181_Composite** image.

Note: these individual bands have spaces in the filenames – spaces can sometimes cause issues when computing in Raster Calculator, especially if you're working in Citrix. If you experience any issues running Raster Calculator in the following steps, right-click on the individual bands and choose Data and then Export Data. From here, you can save each of the bands and name logically and with no spaces.

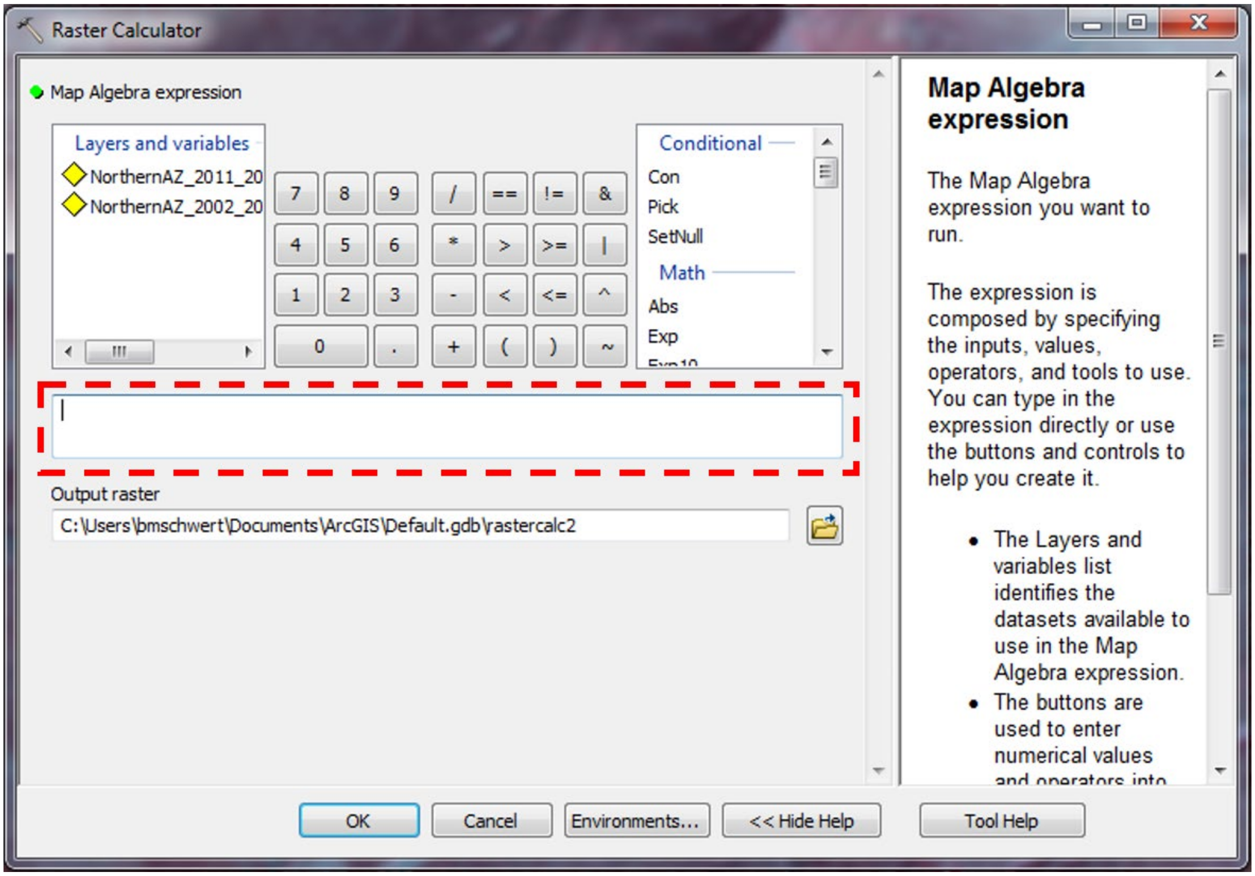
C. Create Normalized Burn Ratio (NBR) images

1. Open the **Raster Calculator**.
   i. Click the **ArcToolbox button** (shown below), and then click the plus signs next to **Spatial Analyst Tools and Map Algebra**. Double-click on **Raster Calculator**.

2. In the **expression box** (shown below), copy and paste the following formula:

```
Float(("NorthernAZ_2002_2002_152_181_Composite.tif - Band_4" -
"NorthernAZ_2002_2002_152_181_Composite.tif -
Band_6"))/Float(("NorthernAZ_2002_2002_152_181_Composite.tif - Band_4" +
"NorthernAZ_2002_2002_152_181_Composite.tif - Band_6"))
```

Note: NBR is calculated by taking the difference of the near infrared and shortwave infrared bands and dividing it by the sum of those bands: (NIR-SWIR)/(NIR+SWIR). In the equation above, we specify both the numerator and the denominator of the equation as float data types so that our output NBR file is also in a float data type. Were we not to do this, our result would be a byte image (values of 0-255), and all decimal values would be rounded to the nearest integer (either 0 or 1), resulting in an NBR image with *only two unique values. The NDVI image created previously in this exercise included a scalar so that the output integer file would range from 0 to 255 – if you would prefer an NDVI image in a float output, simply adapt the equation above for NDVI.*



3. Click the **yellow folder icon** next to the **Output raster field**, choose your **working directory**, and name your output **NorthernAZ_2002_NBR.tif.** Select **Save**.
4. Click **OK** to run.

Note: It is very important to include the .tif extension.

5. Repeat the process for the 2011 image.

Part 3: Create Tasseled Cap transformations

Unlike the single-band indices created previously, the Tasseled Cap is a transformation that takes the six optical bands from Landsat and compresses the spectral data they contain into three biophysically meaningful bands: brightness, greenness, and wetness. The three bands are calculated separately and then optionally layer-stacked afterward.

A. Create Tasseled Cap transformations

1. Click the **Add Data** button and add the remaining individual spectral bands (Bands 1, 2, 3, and 5) from each Landsat composite to the viewer.
2. Open **Raster Calculator**.
3. Copy and paste the expression below into the Raster Calculator window to create the **brightness band**:

```
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_1" * .3561) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_2" * .3972) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_3" * .3904) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_4" * .6966) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_5" * .2286) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_6" * .1596)
```

4. Click on the yellow folder icon, navigate to your working folder, and specify the output as **NorthernAZ_2002_TCT_Brightness**.tif – click Save.
5. Click OK to run.
6. Repeat for the greenness band, using the expression below, and naming the output NorthernAZ_2002_TCT_Greenness.tif:

```
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_1" * -.3344) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_2" * -.3544) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_3" * -.4556) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_4" * .6966) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_5" * -.0242) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_6" * -.263)
```

7. Repeat for the wetness band, using the expression below, and naming the output NorthernAZ_2002_TCT_Wetness.tif:

```
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_1" * .2626) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_2" * .2141) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_3" * .0926) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_4" * .0656) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_5" * -.7629) +
("NorthernAZ_2002_2002_152_181_Composite.tif - Band_6" * -.5388)
```

8. Repeat steps 2-7 using the 2011 imagery.

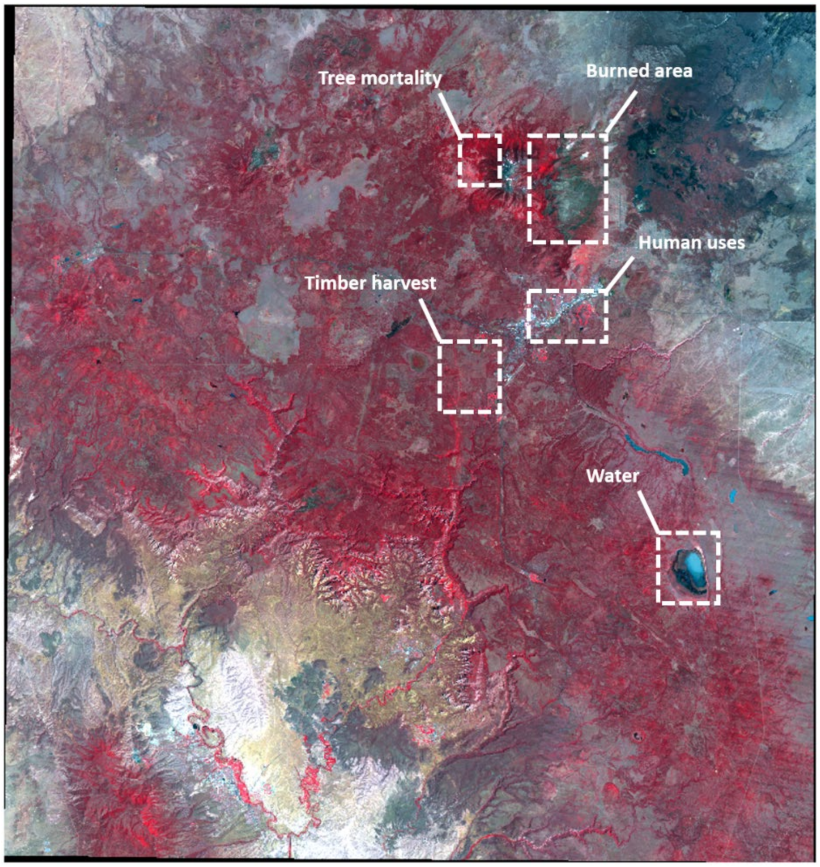
Note: The coefficients used to create the Tasseled Cap transformations are specific to the sensor used, and therefore the creation of these transformations is limited to sensors for which coefficients have been calibrated. In the case of the GEE cloud-free composites, pixels from multiple Landsat images (and potentially from multiple Landsat sensors) may be used to create each image. Here, we are using the Tasseled Cap coefficients for the Landsat 7 sensor. Differences between coefficients for Landsat sensors are minimal, and this is becoming common practice among GEE users.

Part 4: Review and Explore the image enhancements

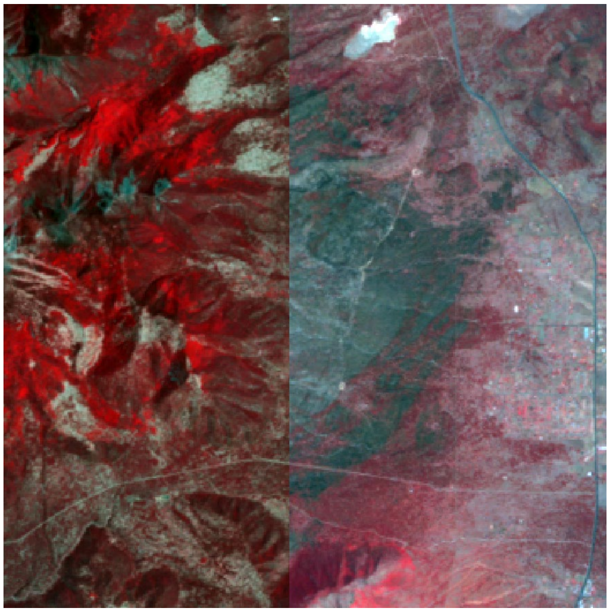
The goal of this portion of the exercise is to get you more accustomed to thinking critically about both imagery and method choices for potential change detection studies. We will be looking at a variety of land cover change types within our scene using each of the image enhancements created in Parts 2 and 3 of this exercise.

A. Setup your map window

1. Remove the individual bands from the **Table of Contents**.
   i. Hold down the **CTRL** key and select each of the individual image bands.
   ii. Right-click the selected layers and select **Remove**.
   iii. Turn off the image enhancements by unchecking the boxes next to them in the **Table of Contents**. You should be left with just the two Landsat images displayed as color infrared (4-3-2) composites.
2. Use the **Zoom** and **Pan** tools to navigate to each of the highlighted change types in the graphic below.



3. At each location, use the **Swipe** tool to view how the landscape changed between 2002 and 2011. (If you need to turn this on, right-click within the toolbar and select the Effects toolbar to enable it.) In the graphic below, the Swipe tool is being used to investigate the spectral changes in the burned area highlighted in the graphic above.



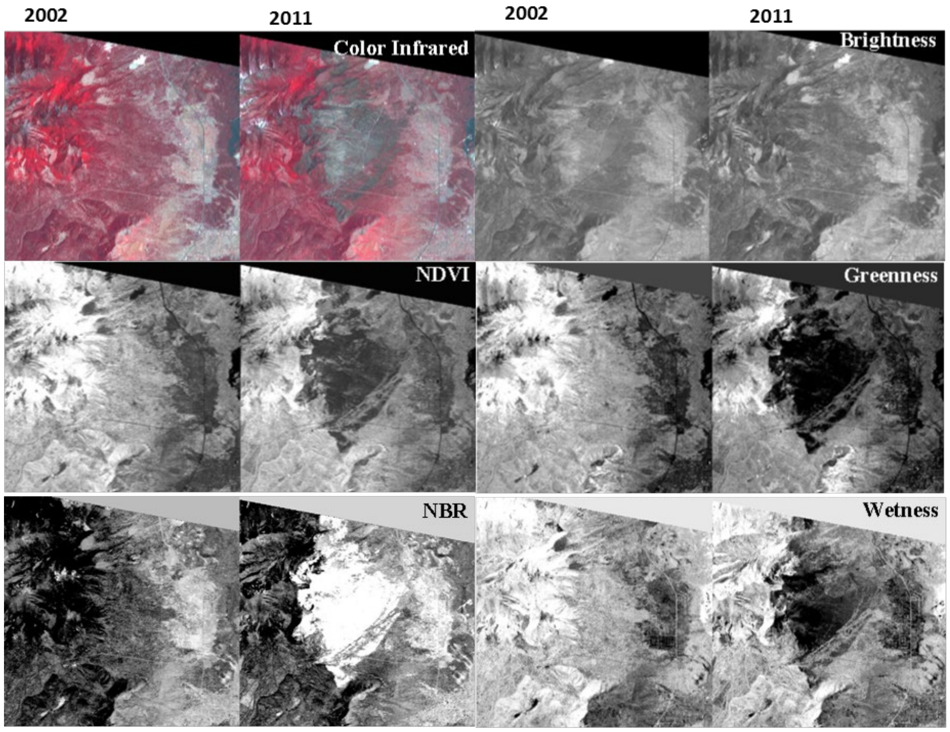
Note: These areas represent prevalent change types within the imagery. Though not an exhaustive summary of changes, these subsets will serves as a basis for the image exploration and interpretation. For each image enhancement, recall which spectral information was used to create it, and try to use this information and what you know of it and the biophysical properties of the landscape to interpret it.

B. Investigate a burned area

1. Using the graphic on the previous page as a guide, navigate to the burned area.
2. In the **Table of Contents**, check the boxes next to the **two NDVI images**.
3. Use the **Swipe** tool to assess how visible this type of change is through the lens of NDVI.
4. Repeat the process for **NBR** and each of the **Tasseled Cap transformations** (brightness, greenness, and wetness).
5. Uncheck the image enhancements, returning to view the color infrared composites in the display.

Knowing what you know about the information required to create each image enhancement, can you explain why the features in each enhancement appear as they do? Which enhancement would best map this type of change? Which would you avoid using to map this type of change?

Hint: remember that brighter values (white) indicate a stronger response, while darker values (black) indicate a weaker response.



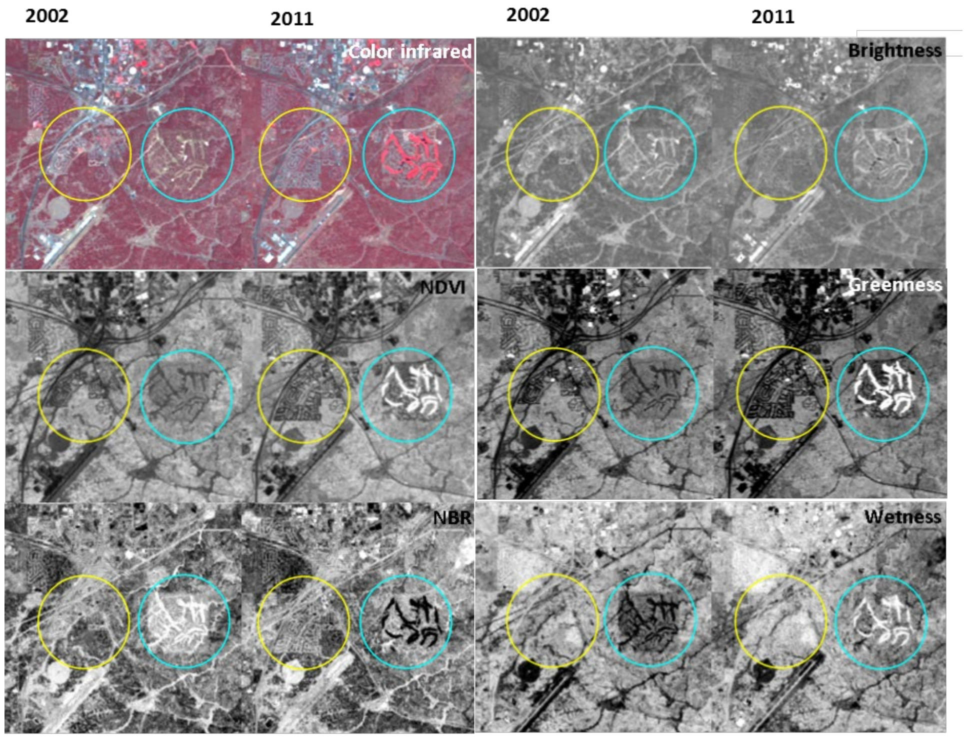
Note: In the color infrared Landsat images, we can clearly see a forest in 2002 (pink/red) transition to a non-vegetated patch of land in 2011 (light blue/grey). This is a burned area from a 2010 wildfire. If we think about the effects that fire has on vegetated landscapes, these image enhancements are logical descriptors of the area. The near infrared band, which is used to create both the NDVI and NBR images, is sensitive to the presence of vegetation. The shortwave infrared band, which is also used to create the NBR image, is sensitive to the presence of water. The Tasseled Cap transformations for greenness and wetness favor the near infrared and shortwave infrared bands, respectively.

C. Investigate human uses of change

1. Using the graphic on the previous page as a guide, navigate to the area of human use changes.
2. In the **Table of Contents**, check the boxes next to the **two NDVI images**.
3. Use the **Swipe** tool to assess how visible this type of change is through the lens of NDVI.
4. Repeat the process for **NBR** and each of the **Tasseled Cap transformations** (brightness, greenness, and wetness).
5. Uncheck the image enhancements, returning to view the color infrared composites in the display.

In which enhancement is the expansion of the subdivision the most evident? Why do you think the golf course is so highly contrasted in the NBR and wetness images?

Hint: Think about the landscaping practices required to maintain a golf course and how they relate to water usage.

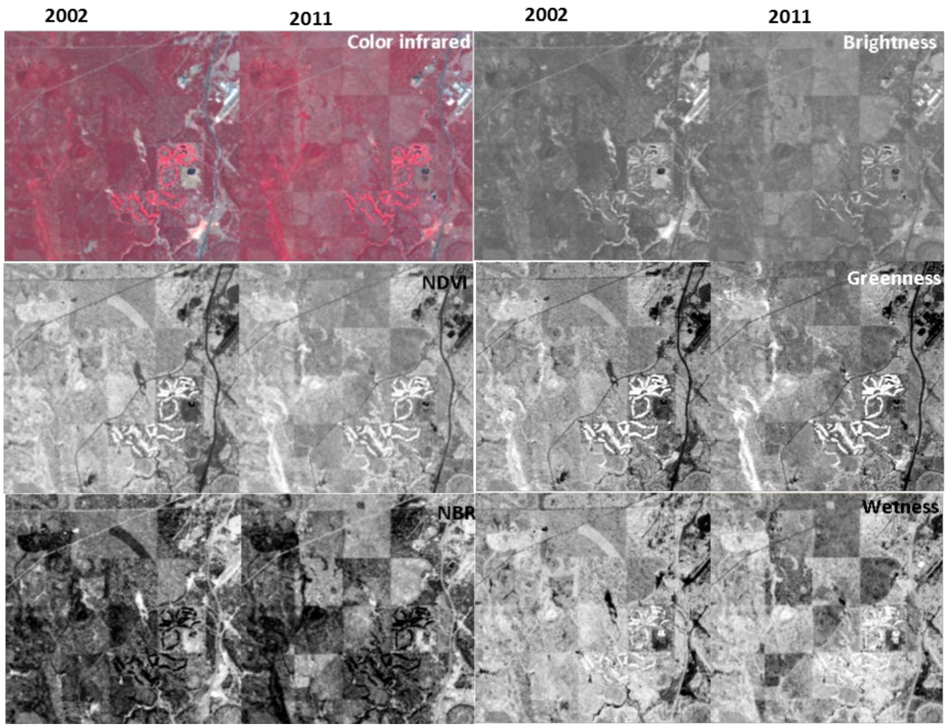


Note: There are two spectrally different types of human use changes occurring in this image: (1) development of impervious surfaces (yellow circle) and (2) completion of a golf course (cyan circle). In 2002, we can see a small residential subdivision and the beginnings of a golf course (sod or seed has not yet been placed). By 2011, the subdivision has grown considerably and the golf course has been completed, as evidenced by the very bright red fairways and greens in the color infrared imagery (high NIR reflectance).

D. Investigate a timber harvest

1. Using the graphic on the previous page as a guide, navigate to the area of timber harvest.
2. In the **Table of Contents**, check the boxes next to the **two NDVI images**.
3. Use the **Swipe** tool to assess how visible this type of change is through the lens of NDVI.
4. Repeat the process for **NBR** and each of the **Tasseled Cap transformations** (brightness, greenness, and wetness).
5. Uncheck the image enhancements, returning to view the color infrared composites in the display.

After looking at the forested plots in the color infrared images, which appear to be healthy and vegetated in both time periods, do any of the image enhancements show evidence of spectral change? If so, which one[s]? Using what you know about image spectra, can you explain why change does or does not appear in the images?



Certain aspects of change within the forested plots are evident in each of the image enhancements. Increased harvest and therefore increased soil background have led to an increase in Brightness values. Likewise, the same plots that have experienced this increase also reveal a decrease in both Greenness and Wetness. These decreases are logical consequences to an increase in visible soil, which will inevitably be less green and less wet than vegetation. The NBR images show the most contrast between the plots, because NBR makes use of both NIR and SWIR bands.

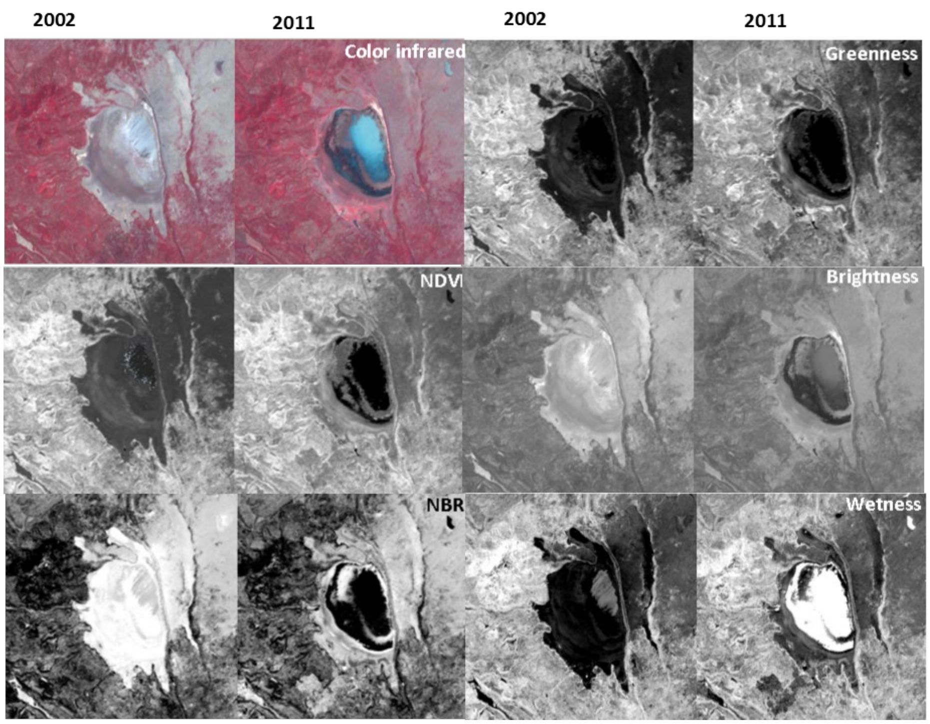
Changes in vegetation are common, though they do not always indicate true land cover conversion. Rather, they may represent seasonal or phenological changes, a state or health change, or a change in resource use. Plots can rotate between dry and wet soils, vegetated and fallow, and within vegetated periods there can be myriad stages of growth or cutting/harvesting—all of these characteristics affect how a plot will appear spectrally in remotely sensed data. In these images, we can see the effects of systematic timber harvest on forested lands.

E. Investigate changes in water

1. Using the graphic on the previous page as a guide, navigate to the water body.
2. In the **Table of Contents**, check the boxes next to the **two NDVI images**.
3. Use the **Swipe** tool to assess how visible this type of change is through the lens of NDVI.
4. Repeat the process for **NBR** and each of the **Tasseled Cap transformations** (brightness, greenness, and wetness).
5. Uncheck the image enhancements, returning to view the color infrared composites in the display.

If water is the feature that is undergoing change, why does the Greenness image show so much change around the water body? Why are changes in the water body and surrounding area so highly contrasted in the NBR image?

Hint: Think about how increased water levels will affect surrounding soil moisture, and in turn, how that will affect nearby vegetation growth.



Water has a distinct spectral signature, so changes tend to be fairly easy to detect. In the images below, we can see that water levels have changed drastically between 2002 and 2011. In 2002, the area is characterized by a small patch of water (though its boundary may be difficult to discern in the color infrared image) surrounded by dry, bare soil. By 2011, water levels have increased such that the area that the water body covers includes much of what was previously bare soil in 2002.

With increasing water levels, the soil moisture in the surrounding areas is also increasing. This increase in water availability allows for increased growth in vegetation, which manifests as an increase in Greenness. The high contrast between image dates in the NBR images is a result of the combined increase in water (in both the water body and the surrounding soils) as well as the increase in vegetation in the area surrounding the water body. Remember that NBR uses NIR and SWIR, the two bands sensitive to changes in vegetation and water, respectively.

Congratulations! You have completed the exercise, creating both indices (NDVI and NBR images) and image transformations (Tasseled Cap) for the two Landsat composites. You have also examined and interpreted how different landscape features and change types look through the lenses of image composites and image enhancements, demonstrating that landscape features and changes have different spectral characteristics. You are now ready to standardize these image enhancements.