Working with the difference Normalized Burn Index - Using spectral remote sensing to understand fire

Learning Objectives

After completing this tutorial, you will be able to:

- Calculate `dNBR` in `R`
- Be able to describe how the `dNBR` index is used to quantify fire severity.

What you need

You will need a computer with internet access to complete this lesson and the data for week 6 of the course.

{% include/data_subsets/course_earth_analytics/_data-week6-7.md %}

Calculate Normalized Burn Ratio (NBR)

The Normalized burn ratio (NBR) is used to identify burned areas. The formula is similar to a normalized difference vegetation index (NDVI), except that it uses near-infrared (NIR) and shortwave-infrared (SWIR) portions of the electromagnetic spectrum (Lopez, 1991; Key and Benson, 1995).

The normalized burn ratio (NBR) index uses the shortwave-infrared (SWIR) and near-infrared (NIR) portions of the electromagnetic spectrum.

The NIR and SWIR parts of the electromagnetic spectrum are a powerful combination of bands to use for this index given vegetation reflects strongly in the NIR region of the electromagnetic spectrum and weekly in the SWIR. Alternatively, it has been shown that a fire scar which contains scarred woody vegetation and earth will reflect more strongly in the SWIR part of the electromagnetic spectrum and beyond (see figure below).

Plants reflect strongly in the NIR portion of the spectrum but spectrun. reflect much less strongly in the SWIR portion which makes this combination powerful for identifying areas with standing dead stems (fire scarred wood / bark) and soil / earth. Source: US Forest Service

NBR Bands

The NBR index was originally developed for use with Landsat TM and ETM+ bands 4 and 7, but it will work with any multispectral sensor with a NIR band between 760 - 900 nm and a SWIR band between 2080 - 2350 nm. Thus this index can be used with both Landsat 8, MODIS and other multi (and hyper) spectral sensors.

Difference NBR

The Normalized Burn Ratio is most powerful as a tool to better understand fire extent and severity when used after calculating the difference between pre and post fire conditions. This difference is best measured immediate before the fire and then immediately after. NBR is less effective if time has passed and vegetation regrowth / regeneration has begun. Once vegetation regeneration has begun, the fire scar will begin to reflect a stronger signal in the NIR portion of the spectrum (remember that healthy plants reflectly strongly in the NIR portion due to the properties of chlorophyll).

For this reason, the NBR ratio works better in areas like the United States where plant regeneration is expected to occur more slowly. In areas like the tropics which are wet and characterized by rapid regrowth, NBR may be less effective.

To calculate the difference, we subtract the post-fire NBR raster from the pre-fire NBR raster as follows:

difference NBR (dNBR) equation. Source: http://gsp.humboldt.edu/olm_2015/Courses/GSP_216_Online/lesson5-1/NBR.html

The classification table below can be used to classify the raster according to the severity of the burn.

SEVERITY LEVEL
Enhanced Regrowth
Unburned
Low Severity
Moderate Severity
High Severity

How severe is severe?

It is important to keep in mind that that the classification table above is one quantitative interpretation of what the results of dNBR actually mean. The term "severity" is a qualitative term that could be quantitied in different ways. For instance, who is to say that .5 couldn't be representative of "high severity" vs .66?

As scientists, the best way to make sure our classification approaches represent what is actually happening ont he ground in terms of fire severity is to check out the actual conditions on the ground. This process of confirming a value that we get from remote sensing data by checking it on the ground is called validation.

NBR & water - false positives

The NBR index can be a powerful tool to identify pixels that have a high likelyhood or being "burned". However it is important to know that this index is also sensitive to water and thus sometimes, pixels that are classified as "high severity" may actually be water. Because of this, it is important to mask out areas of water PRIOR to performing any quantitaive analysis on the difference NBR results.

NBR & Landsat 8

The table below which shows the band distribution of Landsat 8. These bands are different from Landsat 7. What bands should we use to calculate NBR using Landsat 8?

Landsat 8 Bands

Band	Wavelength range (nanometers)	Spatial Resolution (m)	Spectral Width (nm)
Band 1 - Coastal aerosol	430 - 450	30	2.0
Band 2 - Blue	450 - 510	30	6.0
Band 3 - Green	530 - 590	30	6.0
Band 4 - Red	640 - 670	30	0.03
Band 5 - Near Infrared (NIR)	850 - 880	30	3.0
Band 6 - SWIR 1	1570 - 1650	30	8.0
Band 7 - SWIR 2	2110 - 2290	30	18
Band 8 - Panchromatic	500 - 680	15	18

Band	Wavelength range (nanometers)	Spatial Resolution (m)	Spectral Width (nm)
Band 9 - Cirrus	1360 - 1380	30	2.0

NBR & MODIS

Similarly the table below shows the band ranges for the MODIS sensor. What bands should we use to calculate NBR using MODIS?

Band	Wavelength range (nm)	Spatial Resolution (m)	Spectral Width (nm)
Band 1 - red	620 - 670	250	2.0
Band 2 - near infrared	841 - 876	250	6.0
Band 3 - blue/green	459 - 479	500	6.0
Band 4 - green	545 - 565	500	3.0
Band 5 - near infrared	1230 – 1250	500	8.0
Band 6 - mid-infrared	1628 – 1652	500	18
Band 7 - mid-infrared	2105 - 2155	500	18

```
# load spatial packages
library(raster)
library(rgdal)
library(rgeos)
library(RColorBrewer)
# turn off factors
options(stringsAsFactors = F)
```

```
all_landsat_bands <- list.files("data/week6/Landsat/LC80340322016205-SC20170127160728/crop",
           pattern=glob2rx("*band*.tif$"),
           full.names = T) # use the dollar sign at the end to get all files that END WITH
all_landsat_bands
## [1] "data/week6/Landsat/LC80340322016205-SC20170127160728/crop/LC80340322016205LGN00_sr_band1_crop.ti
## [2] "data/week6/Landsat/LC80340322016205-SC20170127160728/crop/LC80340322016205LGN00_sr_band2_crop.ti
## [3] "data/week6/Landsat/LC80340322016205-SC20170127160728/crop/LC80340322016205LGN00_sr_band3_crop.ti
## [4] "data/week6/Landsat/LC80340322016205-SC20170127160728/crop/LC80340322016205LGN00_sr_band4_crop.ti
## [5] "data/week6/Landsat/LC80340322016205-SC20170127160728/crop/LC80340322016205LGN00_sr_band5_crop.t
## [6] "data/week6/Landsat/LC80340322016205-SC20170127160728/crop/LC80340322016205LGN00_sr_band6_crop.ti
## [7] "data/week6/Landsat/LC80340322016205-SC20170127160728/crop/LC80340322016205LGN00_sr_band7_crop.ti

# stack the data
landsat_stack_csf <- stack(all_landsat_bands)
```

When you have calculated NBR - classify the output raster using the `classify()` function and the classes below.

SEVERITY LEVEL
Enhanced Regrowth
Unburned
Low Severity
Moderate Severity
High Severity

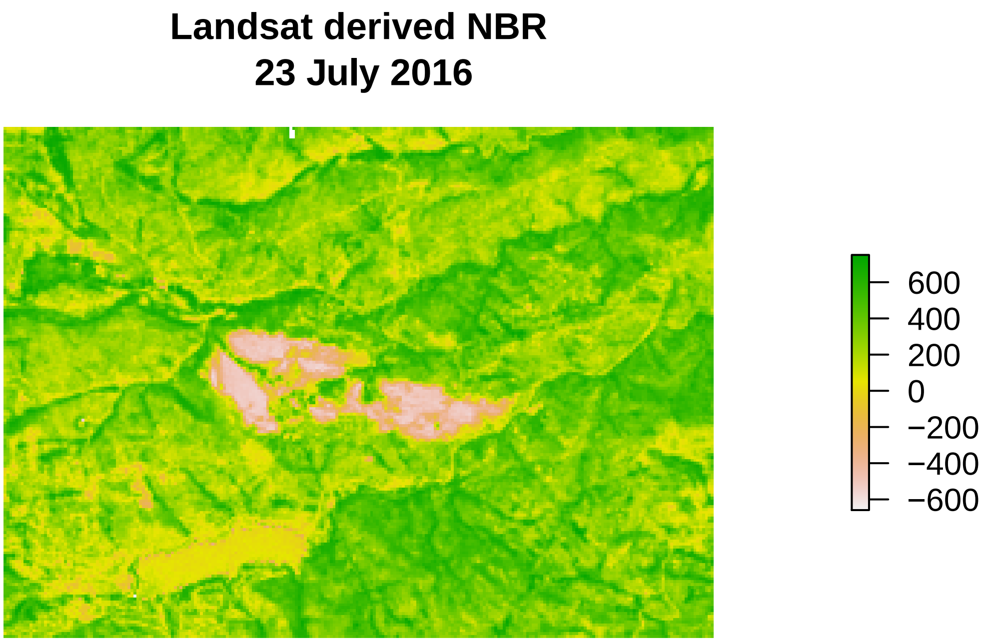

Figure 1: landsat derived NDVI plot

NOTE: your min an max values for NBR may be slightly different from the table shown above! If you have a smaller min value (< -700) then adjust your first class to that smallest number. If you have a largest max value (>1300) then adjust your last class to that largest value in your data.

Alternatively, you can set those values to NA if you think they are outside of the valid range of NBR (in this case they are not).

You can export the rasters if you want.

```
writeRaster(x = nbr_classified,
              filename="data/week6/outputs/nbr_classified.tif",
              format = "GTiff", # save as a tif
              datatype='INT2S', # save as a INTEGER rather than a float
              overwrite = T)

writeRaster(x = landsat_nbr,
              filename="data/week6/outputs/landsat_nbr",
              format = "GTiff", # save as a tif
              datatype='INT2S', # save as a INTEGER rather than a float
              overwrite = T)
```

Your classified map should look something like:

Compare to fire boundary

As an example to see how our fire boundary relates to the boundary that we've identified using MODIS data, we can create a map with both layers. I'm using the shapefile in the folder:

`data/week6/vector_layers/fire-boundary-geomac/co_cold_springs_20160711_2200_dd83.shp`

Add fire boundary to map.

Make it look a bit nicer using a colobrewer palette. I used the `RdYlGn` palette:

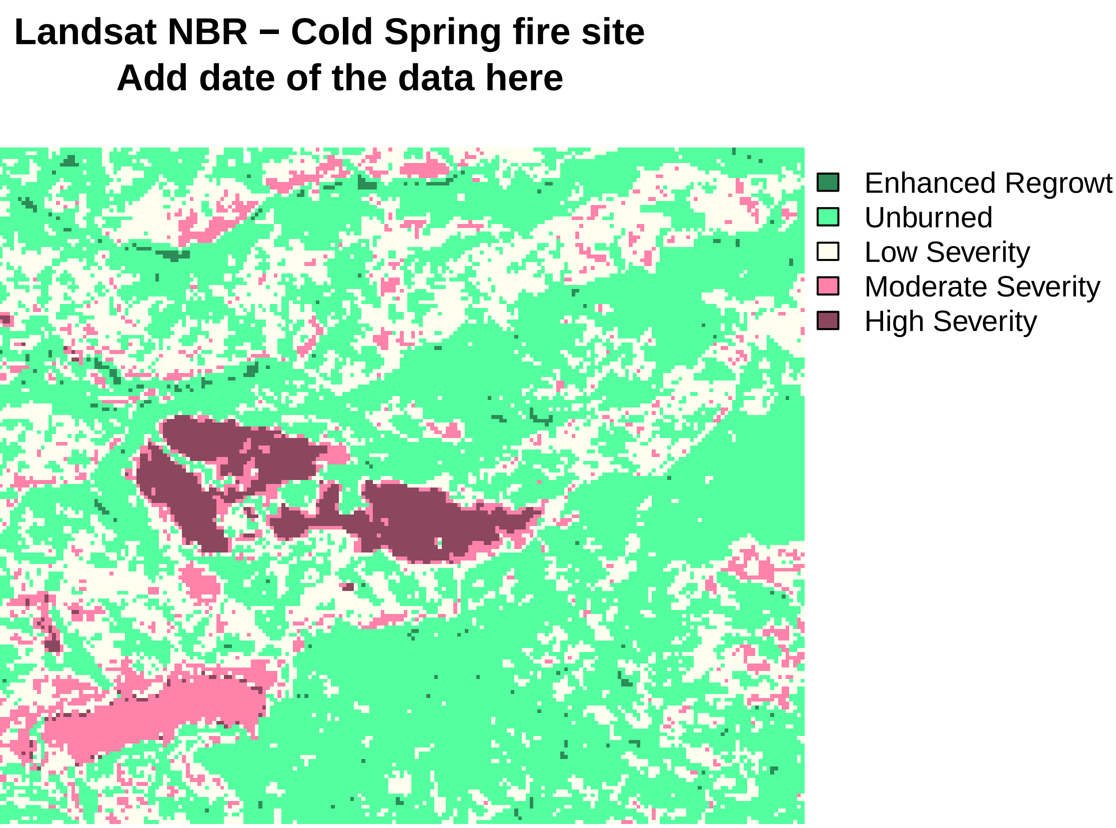

Figure 2: classified NBR output

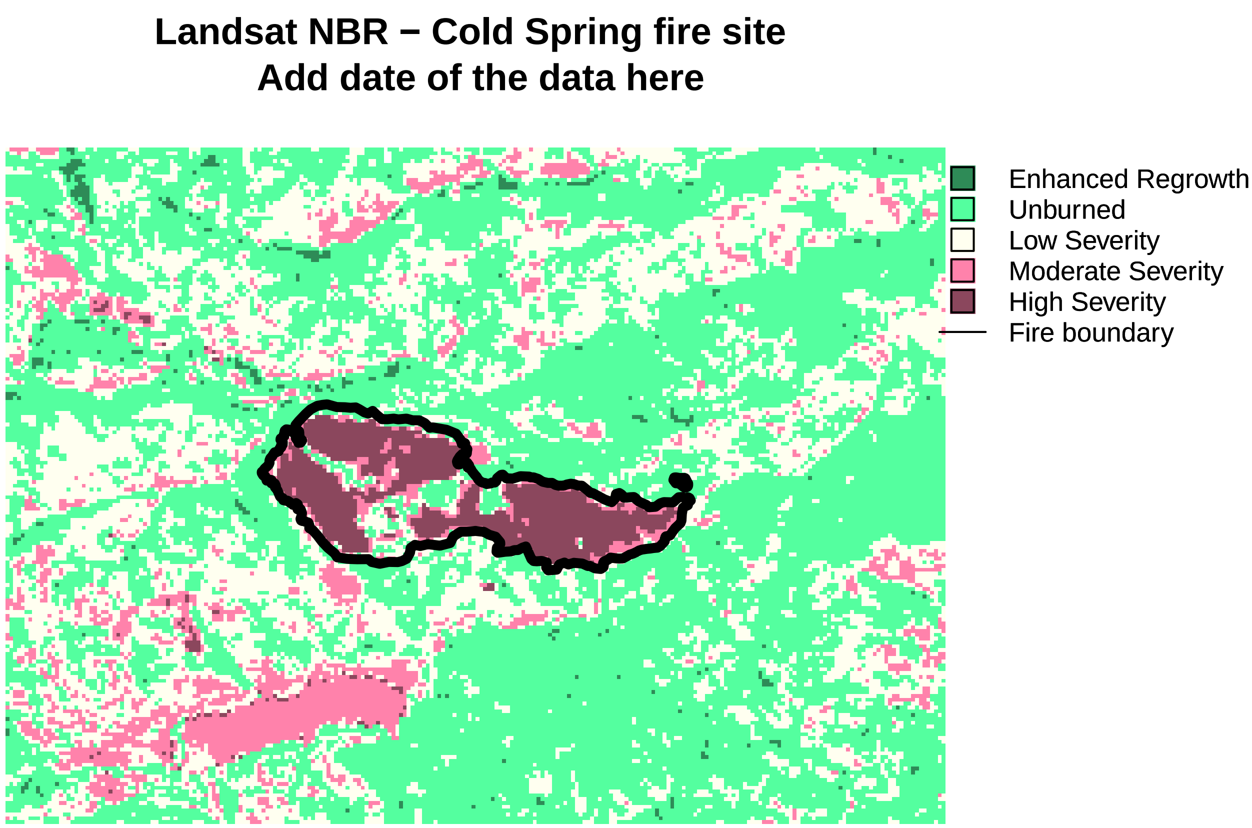

Figure 3: classified NBR output

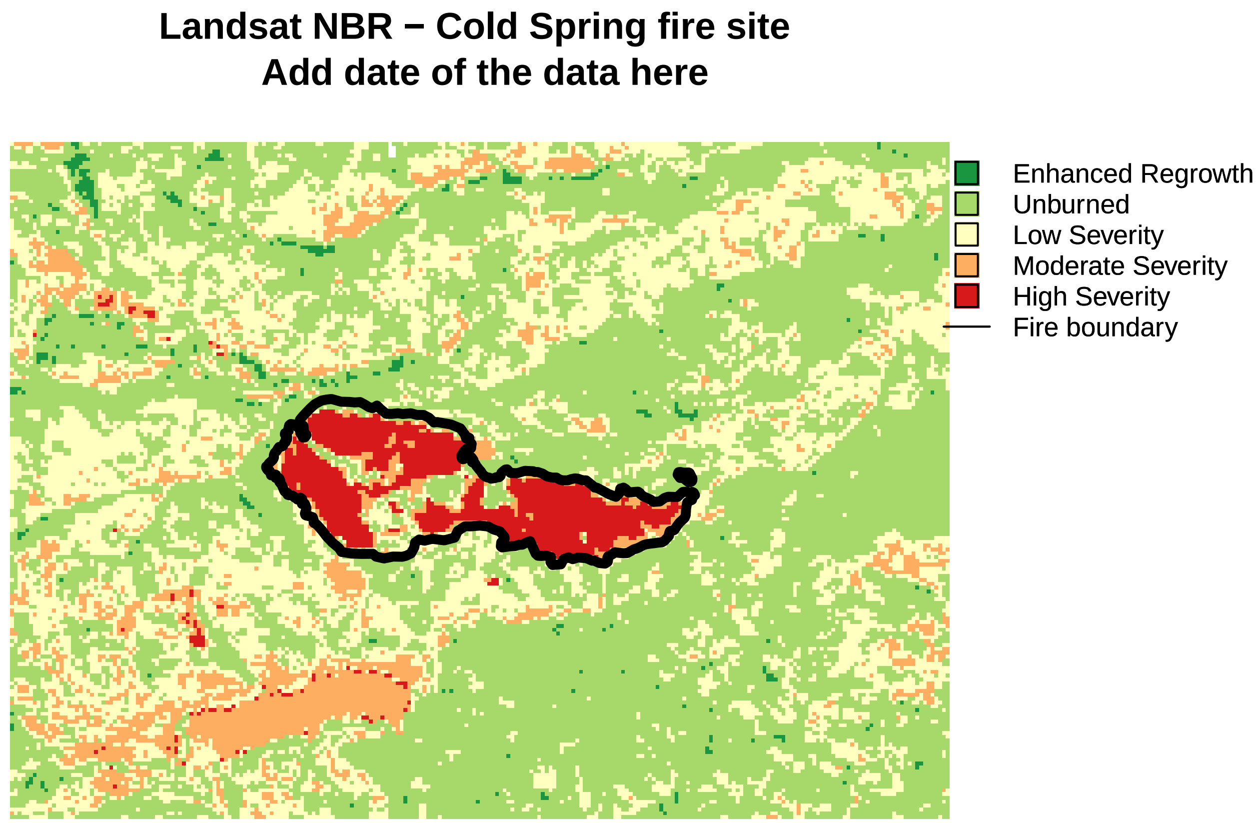

Figure 4: classified NBR output

```
brewer.pal(5, 'RdYlGn')
```

I also did a bit of legend trickery to get a box with a fill. There's probably a better way to do this!

```
legend(nbr_classified@extent@xmax-100, nbr_classified@extent@ymax,
       c("Enhanced Regrowth", "Unburned", "Low Severity", "Moderate Severity", "High Severity", "Fire bo
       col=c(rev(the_colors), "black"),
       pch=c(15,15, 15, 15, 15,NA),
       lty = c(NA, NA, NA, NA, NA, 1),
       cex=.8,
       bty="n",
       pt.cex=c(1.75))
legend(nbr_classified@extent@xmax-100, nbr_classified@extent@ymax,
       c("Enhanced Regrowth", "Unburned", "Low Severity", "Moderate Severity", "High Severity", "Fire bo
       col=c("black"),
       pch=c(22, 22, 22, 22, 22, NA),
       lty = c(NA, NA, NA, NA, NA, 1),
       cex=.8,
       bty="n",
       pt.cex=c(1.75))
```

Note that you will have to figure out what date these data are for! I purposefully didn't include it in the title of this map.

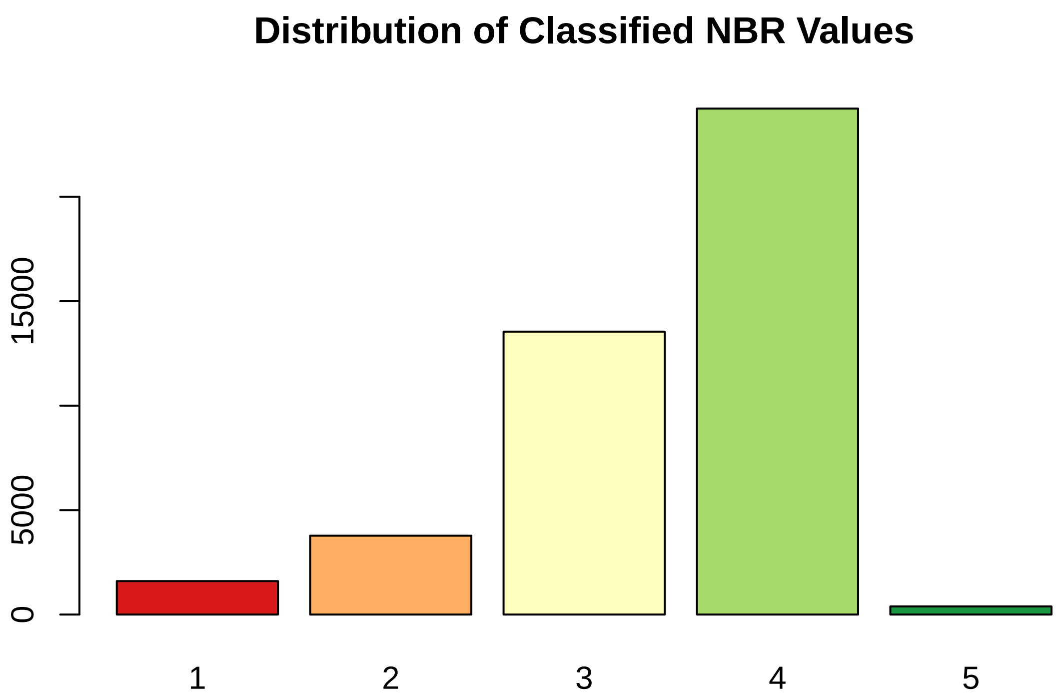

Figure 5: plot hist

Additional Resources

- http://gsp.humboldt.edu/olm_2015/Courses/GSP_216_Online/lesson5-1/NBR.html