Remote Sensing 4113
Lab 11 alternate: Vegetation
April 18, 2018

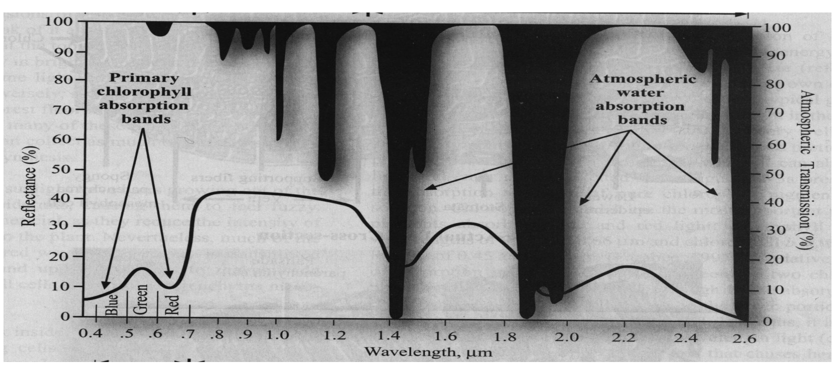
Part I Introduction

The lab instructions consist of three parts: 1) an introduction/background section, 2) a set of specific instructions regarding data to analyze and results to obtain, and 3) an explanation of the ENVI instructions needed to carry out the work in section 2. As in past computer labs, create a `lab_11` directory on your local machine in your personal directory. Download from the class website and unzip the `lab_11_data` file. When finished mail your report to the TA.

A variety of indexes and transformations are used for recognizing and characterizing vegetation. As discussed in class, two common indexes are the simple ratio, SR = Near-IR / Red, and the Normalized Difference Vegetation Index, NDVI = (NIR-Red)/(NIR+Red). A more complicated transformation using Landsat Bands 1,2,3,4,5,7 is called the Tasseled Cap because a resulting scatter plot of two output parameters (“Greenness” vs. “Brightness”) resembles such a hat. All these indexes rely heavily on the fact that vegetation is highly reflective in the Near IR but dark in the Red band. To a greater or lesser extent they try to remove confusion which could be caused by non-vegetation differences.

This lab will explore producing SR, NDVI, and Tasseled Cap indexes from a Laramie Valley Landsat image.

For reference a reflection spectrum of vegetation, and a list of the Landsat TM bands, is included below.



TM Band #	Wavelengths (µm)
1	0.45 – 0.52
2	0.52 – 0.60
3	0.63 – 0.69
4	0.76 – 0.90
5	1.55 – 1.75
7	2.08 – 2.35
6	10.40 – 12.50

Part II: Specific Lab Instructions

We will use the Landsat TM image of the Laramie Valley obtained 17 June 1991, which we also used in an earlier lab. (Use the version in the lab_11 folder. This version has the unneeded TIR band 6 removed. Its presence (in for example the Lab 4 data) causes some problems with the ENVI routines used here.) This time we will use the ENVI calibration routines to convert the raw (0-255) TM data numbers to reflectance, then will compute various vegetation indexes and related transformations, and will examine the results.

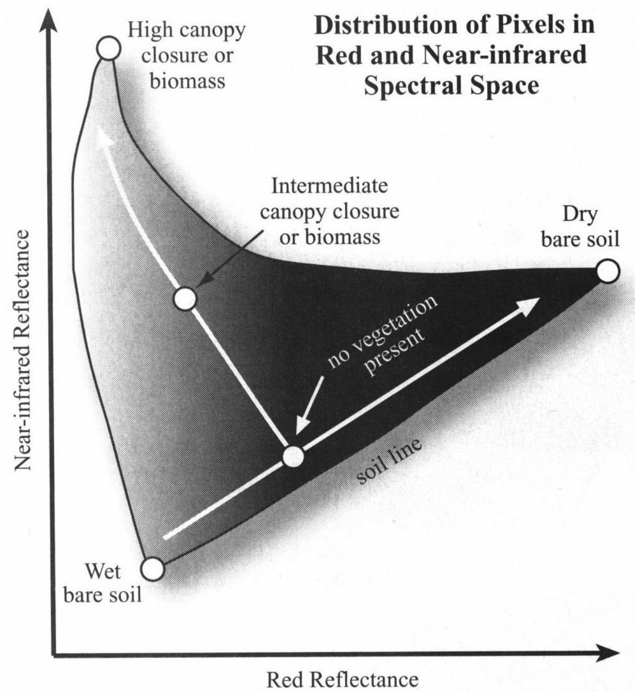
1) ENVI will need the solar elevation angle (the angle of the sun above the horizon) in order to determine how much incoming solar radiation there is, so it can calculate calibrated reflectance values. To find an approximate value we can use the Solar Position Calculator at <http://www.srrb.noaa.gov/highlights/sunrise/azel.html>. Open a web browser and enter that URL. On that web page under "City" tell it you want to specify the latitude and longitude (since Laramie isn't in its list) then enter (105º36' W, 41º25' N). Tell it that the offset between local time and UTC (Greenwich Mean Time) is 7 hours, and tell it NOT to use daylight savings time since the value we will enter will be in standard time. Finally, enter the above date of the observations and enter the approximate local time (9:30 AM Standard Time) when Landsat passes over our latitude. Click Calculate_Solar_Position then write in your lab report the Solar Elevation and Solar Azimuth. Discuss in a sentence or two whether those values are reasonable.

2) **See the note below if you have problems with this step.** Using the main ENVI menu open the Laramie Landsat TM file, and as described in the computer instructions, convert the raw data to Reflectance (not radiance). Save the results to an ENVI format image file so you can read it back if needed. The data should also appear in the available Band List window.

   A bug was introduced in ENVI 4.6.1 which was fixed for a while but as of now (2018) is back again. It prevents ENVI from calibrated the "raw" or "uncalibrated" TM data file. Try to calibrated it so you'll know how the procedure SHOULD work but if you receive an error message, for the following steps open the "calibrated" file provided, which I produced with an earlier version of ENVI. That calibrated file is the one with _cal in the name.

3) Load bands 432 (NIR-Red-Green) of the just calibrated image as RGB. Save a jpg copy of the image for inclusion in your report. From the Image menu select `Tools->Cursor Location/Value` to open a window which lists those quantities. Move around the image and determine typical values for the NIR, Red, and Green reflectances in several different types of terrain (at least the following: Water, Thick Vegetation, Plains, and Urban Areas). Write those in your report and discuss briefly whether the numbers you are obtaining seem reasonable for reflectances. (Note – you will probably want to use the scroll and main image windows to move around, then read values while the cursor is in the zoom window.)

4) Create a 2-D scatter plot (see the computer instructions) with the calibrated TM3 (Red) band on the X axis and the calibrated TM4 (NIR) band on the Y axis. That scatter plot should look roughly like the following tilted "Tasseled Hat" figure. Use the color highlighting / classifying techniques described in the computer instructions for scatter plots to divide the "tasseled hat" into 6 colored coded regions: high biomass, intermediate biomass, low biomass, wet bare soil, moist bare soil, and dry bare soil. When you color a region of the scatter plot the corresponding pixels in the main image window will also be colored. Try this a few times to get an "optimum" choice of regions which separate out the different levels of biomass and different amounts of moisture in the image. Save copies of both the color coded scatter plot and the color coded image for inclusion in your report. (So that you can see the different classes in the image you will probably just want to save an image of the Laramie area and the nearby rivers and meadows, rather than the entire scene. See the "Saving as an Image File ..." computer instructions on how to do this.) Discuss in a few sentences how well the classification has worked in terms of recognizing the different regions.



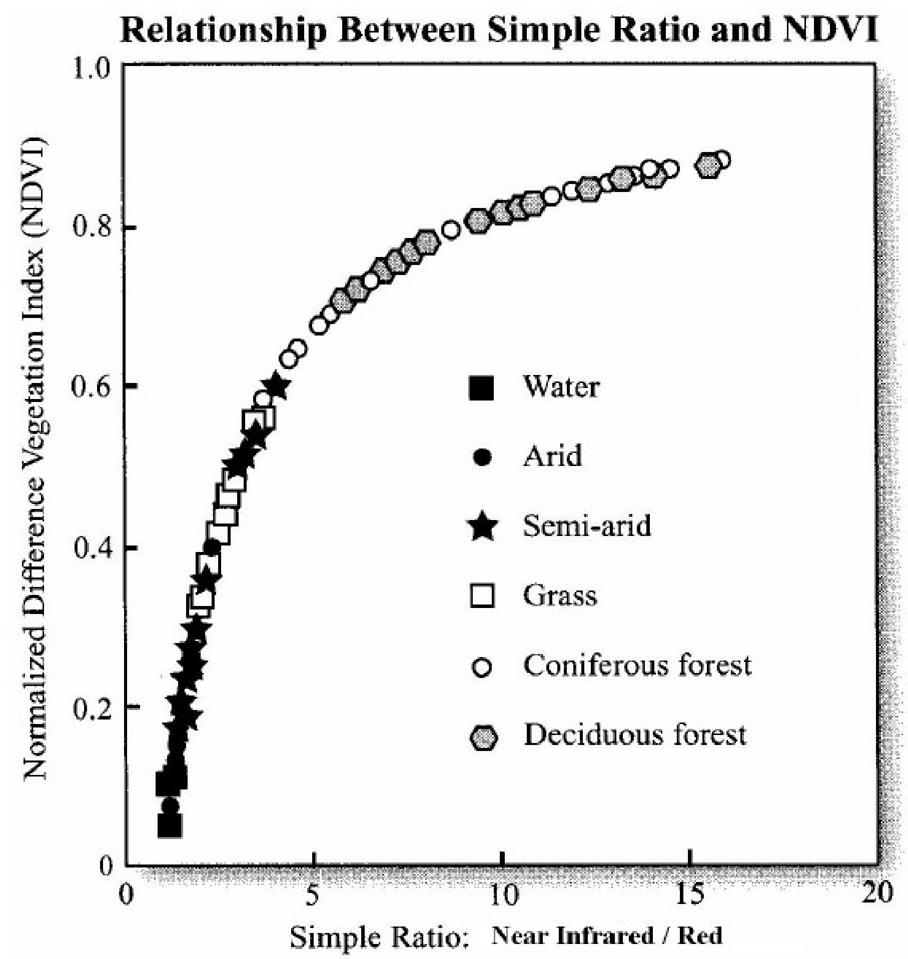
5) Using Band Ratios (see computer instructions) create a "Simple Ratio" (SR, also sometimes called a Ratio Vegetation Index) of Band 4 / Band 3 and save it to a file. Load this as gray-scale into a second display and record typical values for the Ratio both in thick vegetation and in the other areas. Save as a jpg file the same portion of this that you saved in part 4, for inclusion in your report.

Create an NDVI index map using the computer instructions at the end. (You could use band math to do this but ENVI has a built in function.) Load this as gray-scale into a third display and record typical values both in thick vegetation and in the other areas. Save as a jpg file the same portion of this that you saved in parts 4 and 5. Compare the images from parts 4, 5, and 6 and discuss in a few sentences how well the SR and NDVI indexes recognize the regions of vegetation. Measure and record the value of the SR and the NDVI in the different types of terrain discussed above.

We can empirically determine the relative calibration of the SR and the NDVI curves shown below from Jensen Figure 11-21 by creating a 2-D scatter plot with our SR curve as the X axis and our NDVI curve as the Y axis. Produce that plot. From the scatter plots menu use Options -> Set X/Y axes ranges to adjust the axis to be the same as in Figure 11-21. Save the plot for inclusion in your report. Note we have to get the same result if we've done the calculation correctly since

NDVI = (B4-B3)/(B4+B3) = (B4/B3 – 1) / (B4/B3 + 1) = (SR – 1) / (SR + 1) .

Does your curve in fact match that shown below?



6) ENVI also contains routines to calculate the "Tasseled Cap" transformation. As described in the computer instructions, this transforms our calibrated data to create the "Brightness", "Greenness", and "Third" channels. The "Third" channel is related to wetness and soil type. Load the "Greenness" channel into a (4^{th}) gray-scale display, save a copy for inclusion in your report, and compare the resulting image to the SR and NDVI ones. Next, load all three bands into your 4^{th} display, with (Third, Greenness, Brightness) = (RGB). Save a jpg image for inclusion in your report. Finally, from the image's menu select `Tools -> 2D Scatter Plot`, and create a scatter plot with `Brightness` on the X axis and `Greenness` on the Y axis. Save a copy for inclusion in your report. You should obtain a plot very similar to that from Part 4, except it has now been rotated so the "bare ground" line is more-or-less horizontal while the increasing biomass line is more-or-less vertical. (In reality the tasseled cap is still slightly rotated – probably because of some inaccuracies in the calibration of our reflectances.) When calibrated and rotated properly we could use the Y ("Greenness") Axis as a direct measure of biomass. As described in the lecture, we could also use such a plot to follow the changes in a crop throughout the growing season.

Summary: Your report should contain:

1. The solar elevation and azimuth for the observations, and a brief discussion of whether your values are reasonable.

2. A (NIR, Red, Green) color-infrared version of the calibrated image (for reference) and also a table giving the NIR, Red, and Green reflectances in several types of terrain. You should also discuss whether those values are reasonable.

3. A 2-D scatter plot of NIR vs. Red, color coded into at least 6 different regions, accompanied by the color coded version of the image. You should also discuss how well the scatter plot properly classifies the different types of terrain.

4. The SR and NDVI images, typical values for these indexes in the different types of terrain, and a discussion of how well these images measure vegetation.

5. The NDVI vs. SR calibration curve produced by a scatter plot.

6. The Tasseled Cap Greenness image (shown as gray-scale) and a comparison with the above vegetation results. The color image using all three tasseled cap bands, and the scatter plot of Greenness vs. Brightness

Part III: Computer Procedures

Procedure for Calibration:

From the main ENVI menu select **`Basic Tools->Preprocessing->Calibration Utilities->Landsat TM`**
then in the Input File window select the Laramie TM data file. Use the defaults for the other choices: **`Spatial Subset`** = **`Full Scene`** and **`Spectral Subset`** = **`6`** out of **`6`** bands and click **`OK`**. In the TM Calibration Parameters window which will appear next, select Landsat 5, specify the date information (June 17, 1991) and the solar elevation. Select **`Reflectance`** (not **`Radiance`**). Choose an output file name in your **`lab_13`** directory, then click **`OK`**.

2-D Scatter Plots

From an image window menu select **`Tools->2-D Scatter Plot`**. In the **`Scatter Plot Band Choice`** window which appears, chose the bands to plot as X and Y. After the plot window is opened you can save a copy of it (as a jpg image) using that window's menu: **`File->Save_plot_as`**.
You can also find which regions of the scatter plot correspond to which regions of the image. To define a polygonal region of the scatter plot to investigate, click the left mouse button on the corners of the polygon you want to highlight. After defining all the corners click the right mouse button to close the polygon and "color" both the pixels in the scatter plot and the corresponding pixels in the image. To select the colors to use, from the scatter plot menu select **`Class->Items 1:20`** then pick a color. To clear the colors from the scatter plot menu select **`Option->Clear All`**. Be careful not to move the selection box in your image scroll window or the colors will also be cleared.

Saving as an Image File Just Part of the Scene

To save a copy of just the main image to the window you can use the procedure in the next paragraph, or as a shortcut, you can press the **`Alt`** and the **`Print Screen`** keys to copy the currently active window to the clipboard (**`Alt+F14`** on the Mac keyboards), then just paste that image into your report. When you want to save the image with the overlay colors created by mapping ROI's in a 2-D scatter plot, this window copy is simplest, as the procedure outlined below does not save overlay colors.

When you ask ENVI to save an image (usually in jpg format) it typically saves the full image, as shown in the scroll window. If you want to save just that portion in the main image display window, after selecting
`File->Save Image As->Image File` in the **`Output Display to Image File`** window click **`Spatial Subset`** to override the **`Full Scene`** default. In the **`Select Spatial Subset`** window which will appear, click the **`Image`** button. It will bring up a small image display with the current

"main image window" area outlined in a red box. Just click **OK** to accept that subscene, or drag the box or its corners to adjust the part of the scene to save.

Band Ratios

To compute band ratios (we did this in an early lab) from the main ENVI menu select **Transform->Band Ratios** then in the **Band Ratio Input Bands** window which will appear select the bands to use as the numerator and denominator, and click **Enter Pair**. In the **Band Ratios Parameters** window which will appear accept the default **Spatial Subset** = **Full Scene**, choose an output file name in your own directory, and click **OK**.

NDVI Calculation

To calculate the NDVI for an image from the main ENVI menu select **Transform-> NDVI** then in the **NDVI Calculation Input File** window which will appear select the calibrated image, accept the default **Spatial Subset** = **Full Scene**, and click **OK**. In the **NDVI Calculation Parameters** window which will appear, accept what should be the default **Input File Type** = **Landsat TM**, and the **NDVI bands Red**=**3**, **NIR** = **4** (or change them if these are wrong), choose an output file in your directory, accept the default **Output Data Type** = **Floating Point**, and click **OK**.

Tasseled Cap Transformation

For Landsat TM data this transforms the six visible through SWIR bands into three bands labeled "Brightness", "Greenness", and "Third". Other variants are available for Landsat MSS or ETM data. From the main ENVI menu select **Transform -> Tasseled Cap** then in the **Tasseled Cap Transform Input File** window which appears select the calibrated Laramie data, select the default **Spatial Subset** = **Full Scene**, and click **OK** . Click **Input File Type** and select **Landsat 5 TM** then chose an output file in your own directory.

Comparing two different images

To compare images you can also load your classification results as a **Gray Scale** image on a **New Display** – then use the **Tools->Link->Link Displays** menu of that new display to link it to the original color-infrared image, or to another classification image. Holding down the left mouse button within one image causes the other one to momentarily appear.