

# GEO 427/EVS 527

## Dark Object Subtraction, Band Ratios, Multiband Indexes, and Spectral Libraries

In this exercise, we will look at the reflectances recorded in digital numbers (DNs) from different types of land surface and examine where they come from and how these reflectances can be used to identify various materials or other features of interest. We will start by considering the “dark object” which characterizes most satellite imagery.

The dark object in a satellite image represents the area of zero reflectance across the image. It represents a number of things, including shadow, scattering, and electrical gain in the sensor. Often, especially when we are planning to use band ratios, it is useful to eliminate the dark object from the image. In this laboratory, you will use the ERDAS Imagine spatial modeler to develop a general program to [1] subtract the dark object, [2] take band ratios of the more significant bands in your image, and [3] compare an empirical dark-object-subtracted band ratio to empirical reality.

You should first load a Thematic Mapper image of an area of interest (typically about a quadrangle in area) into your viewer. You may have to subset a scene in order to have a meaningful area. Look at the histograms of the 6 or 7 bands comprising it. The dark object is the zone of DN's with no pixels. It extends from DN = 0 to DN = (the highest value held by no pixels). Verify that the dark object is greatest in band 1 and less in the other reflected bands, and that it may be lacking altogether in bands 5 and 7. In the image you have chosen, are there pixels with a value of zero for band 1?

Write a program using the spatial modeler that subtracts the dark object. The general form for the program will be  $\{\text{image}\} - \{\text{Global Minimum}(\text{Image})\}$  (if there are no pixels of zero value) or  $\{\text{image}\} - \{\text{Global Minimum}(\text{Image}) \text{ Ignore } (0)\}$  (if there *are* background pixels assigned zero value). Be sure that you understand the logic of the model you have written. When you run the model and create a new image, verify that you have subtracted the dark object.

Using the image you've created, write a model in which you calculate two or three representative band ratios for your area of interest. Examples of useful band ratios include Band 4 / Band 3, Band 5 / Band 7, Band 5 / Band 4, and Band 3 / Band 1. Again, be sure that you understand the logic of your spatial model, and look at the images produced by your calculations. Do they register anything of interest?

Now take a look at the indices built into ERDAS Imagine (or whatever other software you are using). You find these by clicking on Interpreter -> Spectral Enhancement -> Indices. Note that some of these are simple band ratios; others are sums of band DN's; still others are ratios of band sums or differences. Click on the “view” button for some of the indices to see their logic. Is it the same as for the simple dark-object-subtracted band-ratio model you wrote? What are the differences?

Now let us continue to look at the reflectances recorded in digital numbers (DN's) from different types of land surface and examine how these reflectances can be used to identify various materials or other features of interest. Specifically, we will look at experimental reflectance data from 146 mineral situations and see how these translate into brightness bands and band ratios.

Using LibreOffice Calc or Excel, open the file. There are two versions of the file: Landsat\_TM\_MSS\_Reflectance.ods (LibreOffice) and Landsat\_TM\_MSS\_Reflectance.xls (Excel). Both are located in the “Spectral Libraries” directory of the R: drive. Note that this workbook contains 4 pages. We will discuss, basically, how each page is derived. You will then verify the contents of each sheet, and we will then set up some specific things to look for.

You should first open the spreadsheet in either Excel or LibreOffice Calc. The icon for both these programs is on your desktop. You will be told that it is read-only (since the R: drive is read-only) and that you will not be able to save changes; click OK. The first tab of the spreadsheet is entitled “Basic

Reflectance Data.” It contains the percentage reflectances of the 6 TM reflected bands (TM band 6, the thermal IR band, is omitted) and the 4 MSS multispectral bands (they are labeled 1-4 here, instead of Bands 4-7, as NASA numbers them). The wavelength limits (in micrometers) of each spectral band are given in the first row of header information, which you should LEARN. Look at the materials (mostly minerals) in the list, and note the variation in the reflectances, both from material to material and from band to band.

The second page of the spreadsheet contains a copy of the first page followed by the ratio of reflectances from each band. There are 15 possible band ratios for the 6 reflected TM bands and 6 possible band ratios for the 4 reflected MSS bands. The column header indicates which bands appear in the ratio. For example, TM21 is the ratio of Thematic Mapper band 2 to TM band 1. This page contains all 21 of these band ratios for each of the 146 materials in the table. For example, the reflectance of the mineral Actinolite in TM Band 1 is 16.095% and in TM band 2 is 17.505%. Therefore,  $TM21 = 17.505 / 16.095 = 1.0876$  for Actinolite. Verify that you understand the significance of the band ratios and that they are being calculated correctly. Note also that the ratio of any two bands (e.g. band2/band1) is the inverse of the ratio of the inverse of the same two bands (e.g. band1/band2).

The next page of the spreadsheet is a quick-look table of brightness codes for the 146 Earth materials in the spectral library. The purpose of this table is to enable you to tell at a glance which spectral bands of MSS and TM a particular Earth material is brightest (a brightness code of 9) or darkest (brightness code of 0). Brightness codes can be used to create images such that certain materials are a desired color, or to interpret a color image that already exists. The primary colors for light are blue, green, and red. A material with brightness codes of 0, 0, and 9 for the three spectral bands selected by the user for display as blue, green, and red, will show up as red in the resulting color composite image. The following table relates the brightness codes to colors in the color composite image:

Brightness code for 3 selected bands	Color in color composite image
0,0,9	Red
0,9,9	Yellow
9,9,9	White
9,0,0	Blue
0,9,0	Green
9,9,0	Aqua (blue-green)
0,0,0	Black

Different color mixtures come about from materials with brightness codes between 0 and 9. Materials with brightness codes of 0, 9, 9 will appear yellow in the resulting image (red plus green equals yellow). Materials with brightness codes of 9,9,9 will appear white in the resulting image. The 9,0,0 and 0,9,0 combinations are blue and green, respectively.

Verify the brightness codes as calculated for the 146 materials in the table, and see if you can derive a better way to calculate brightness codes. The brightness codes were determined by the following procedure. First, the basic reflectance data (i.e. the first page) was sorted for TM band 1, in ascending order, from lowest reflectance to highest. Actual reflectance was replaced by the number 0 for each of the first 15 materials (i.e. those with the lowest reflectance); then 1 for the next 14, 2 for the next 15, 3 for the next 14, and so on until all of the cells were filled with numbers between 0 and 9. This process was then repeated for TM band 2, then 3, and so on until brightness values are calculated for all TM and MSS bands. When the table is complete, it was sorted again by material name to realphabetize it.

To check your understanding of the table, what three-band color composite (there are two possible answers) of MSS would make green grass reddest? What else would appear red? What color

composite of TM bands would make vegetation red, and what else what else might also appear red?

The last page of the spreadsheet is a quick-look table of spectral ratio codes for the 146 Earth materials in the spectral library. Its purpose is to enable you to tell at a glance in which spectral ratios of MSS and TM bands a particular Earth material is brightest (a ratio code of 9) or darkest (ratio code of 0). Again, verify that the table is set up correctly and that you understand its use.

The basic process of creating this quick-look table was the same as used to create the brightness values for the single-bands. We started with the 21 band ratios that were calculated for the TM and MSS data and which appear on the second page of the spreadsheet. The table was sorted separately for each of these 21 band ratios, in ascending order, and the calculated band ratios were replaced with 15 x 0, then 14 x 1, then 15 x 2, then 14 x 3, and so forth until the entire column was filled with brightness values.

To test your understanding of this page, what three LANDSAT TM spectral ratios would yield a color ratio image that made alunite red, yet that best separated alunite from hematite, kaolinite, and vigorous grass? Give the TM ratio codes of each of these four materials for the three TM spectral ratios in this color ratio image. This information will be included in your portfolio.

The tables you have been looking at are derived from a spectral library that included the 146 minerals in the table. The minerals had been ground to a more-or-less uniform powder, and white light was shined on the mixture. A spectrometer measured the percentage of each wavelength of light impinging on the powder that was actually reflected into the sensor. Spectral libraries have become an important resource wherever spectrologic investigations are used to identify unknown materials. The tables you used in exercise 3 were derived from spectral libraries produced by the US Geological Survey, but the Spectral Library Viewer in ENVI includes several others. You will continue this exercise by looking at the raw data which USGS has developed for a library of materials. You should determine a methodology to go from the spectral reflectance curves to the basic inputs to a table such as that presented by Dr. Vincent earlier in this exercise.

Examine at least 25 different materials of interest to you in at least one of the spectral libraries included in the ENVI spectral library viewer. Be sure that you understand the information presented about each material in each of the files. For each of the 25 materials, how would you use the information in libraries such as this to derive a table that would enable you to develop brightness values such as you considered in exercise 3.

Do the 25 materials you chose in this exercise provide an adequate basis to deal with the biological issues we wish to consider in this course? What other materials would you like to consider?

To see if there is a spectral library that includes the materials or issues you would like to consider, carry out a Google (or whatever) search on the internet to locate other spectral libraries. What are most of the spectral libraries you find if you use "spectral library" or "spectral libraries" as your search item? What happens if you use "vegetation spectral library" or "mineral spectral library" or some other specific sort of spectral library of interest? What information do you find?

Be prepared to discuss the derivation of brightness-value tables from the individual spectra. Also be prepared to discuss the spectral libraries you found. The report from which you will begin this discussion will be included in your portfolio.

### **Portfolio**

- 2-1 The band ratios that would yield a color of red for alunite red and which best separated alunite from hematite, kaolinite, and vigorous grass – with an explanation of your logic.
- 2-2 Your report listing the 25 materials of interest and a discussion of the implications of their reflectance from the spectral library.