Lab assignment #2: Detecting change in terrestrial environments with unsupervised methods

1. Logistics

Date assigned:	February 12th, 2016
Date due:	March 2nd, 2016 (in conjunction with lab 3)
Points:	100 points

2. Introduction

The main goal of this lab is for you to detect change using two dates of satellite imagery. To do this, you will compare and contrast two different change detection methods for their ability to effectively and accurately capture land cover changes. You will produce a map of change using each method, and then assess the accuracy of each map using an independent, random sample of test sites.

3. Study areas

For this lab, you will be detecting multi-date changes using unsupervised methods such as image algebra techniques (image differencing) and unsupervised classification (described below). You must use the same image set (one of the following six choices) for each method:

- deforestation in Bolivia
- urbanization in Guangzhou, China
- wetland change in Horicon Marsh, Wisconsin
- flooding in Mali
- forest transitions in Oregon
- agricultural expansion in the Nile River Delta, Egypt

4. NDVI image differencing

One of the simplest change detection methods is image differencing, where the brightness values of one band of one image (date 1) are subtracted from the same band of another (date 2) to achieve a continuous value output image. Intuitively, if there is no change, then the values you would expect from image differencing would be zero. The negative and positive values at the extremes, then, indicate the changed areas. Since the resulting difference image is stretched to display values between 0 and 255, the no change areas will usually appear grey and the change areas will appear as very dark or very bright areas. To create a final *thematic* map of land cover change, you must then density slice the continuous-value output image to label the areas of change and no change.
To perform image differencing on NDVI images, follow these steps:

a. **Open ENVI and display both images**.

First, spend some time mentally or visually locating areas of land use change in the image. You might want to make a note of areas where you would expect to see change, what these changes might be and what caused the change. It is sometimes helpful to make a quick sketch of these areas. This step is critical, since you will need this information to spot-check whether each method is working or if the different parameters require adjustment.

b. **Create NDVI images**.

On the main menu bar, go to

Transform > NDVI

Choose the first image date, and then repeat the process for the second date.

c. **Subtract the NDVI images.**

To start image differencing go to:

ENVI main menu bar > Basic Tools > Band Math

In the ***Enter an expression*** field, enter the following:

float(b1) – float(b2)

Click ***Add to List*** and then ***OK***. Note that you must have your images open before performing this step.

In the new ***Band Math*** window, define your **b1** and **b2** variables for the expression you just entered. Highlight **b1-undefined** in the list and then highlight the NDVI image from date 2. Then highlight **b2-undefined**, and select the NDVI image from date 1. Double check that you are doing the following: date 2 - date 1. Then enter an ***Output File Name*** and hit ***OK***.

d. **Assess the difference image**.

When the image differencing operation is complete, open the output image in gray scale in a new window next to the original two NDVI images. Now, you need to density slice the output image to isolate the areas of change and no change. To select appropriate ranges, you will need to use your reasoning and 'map' of changed areas from step (a).

Zoom specifically to changed areas and use the ***Cursor Location/Value*** tool to determine the output pixel values. At the same time, open the image histogram under the ***Enhance > Interactive Stretching*** option in the image window (you might also wish to run the statistics for the difference image off the main menu bar, at ***Basic Tools > Statistics***). Isolate the parts of the histogram where you believe change has and has not occurred. You are now ready to density slice the image.

e. **Density slice the difference image**.

Go to the image window for your difference image and scroll to:

Overlay > Density Slice…

Choose your difference image as the ***Input*** and click ***OK***. The ***Density Slice*** window appears, which allows you to slice the image values into different intervals based on the desired thresholds applied to the histogram. You will notice that ENVI chooses an initial set of thresholds for you, which may or may not be what you want. Hit ***Apply*** to see what these initial values do to your image.

You may choose to edit these existing ranges, but often, it is best to delete them and start from scratch. Highlight each range and hit ***Delete*** until there are no ranges listed in the window.

Based on the values determined from step (d), define a new set of thresholds/ranges. To add a new range, go to the menu bar on the ***Density Slice*** window and click on:

Options > Add New Ranges

The *Range Start* and *Range End* values will be the minimum and maximum values of the histogram. Then choose a value for the number of ranges you wish to add. The idea is that a value of 10 will provide 10 equal slices for the whole range of values on the histogram.

If this feels too clumsy, you can add ranges one at a time by entering specific min and max values, and only indicating 1 for the number of ranges.

Once you have finished editing the thresholds, hit ***Apply***. As you are editing, make sure that you do not generalize the image too much that you do not capture the changes between the two images.

f. **Save your thresholds to a file**.

It is important that you save your edited ranges to a file. In the ***Density Slice*** window, go to

File > Save Ranges…

Make sure the new file is saved in your own directory. As usual, you can then reopen your threshold ranges by opening the ***Density Slice*** tool and clicking on

File > Restore Ranges…

g. **Create a classified map using the thresholded difference image**.

Although you have effectively made a classified map by applying the density thresholds, in reality, the difference image has not actually been converted into a thematic map. You will need to actually perform an extra step to <u>create a classified map</u> that ENVI recognizes as such (this step is imperative for when you perform an accuracy assessment below). To do this, go to the ***Density Slice*** window and select

File > Output Ranges to Class Image…

Open this new map in a display window and use the ***Cursor Location/Value*** tool to look at the values. Note that the values no longer range from 0-255, but have values of 1, 2, 3, etc., with a label indicating the original range you chose. You can now edit the class labels as you would any other classified map.

5. Multi-date unsupervised classification

In the previous method, you produced a change image with continuous value results that required thresholding to produce a thematic map. A number of methods allow you to create a thematic map directly, such as multi-date unsupervised classification. The idea behind this method is that the classifier (whether supervised or unsupervised) is able to discern patterns of *change* and *no change* in the spectral values of the two image dates.

a. **Create a multi-date image stack**.

To apply this method, you will first need to create a multi-date image stack. In other words, you need to generate a file that has all the bands of both dates of imagery in the same file. On the main menu bar, go to

File > Save File As > ENVI Standard

When the ***New File Builder*** window opens, click on ***Import File.*** Select the first date of your image pair and hit ***OK***. When you return to the ***New File Builder*** window, click on ***Import File*** again. Choose the second date and hit ***OK***. Choose a file name in your own directory and hit ***OK***.

b. **Run the unsupervised classification algorithm**.

Once the new multi-date image has been created, you can go directly to the main menu bar and click on

Classification > Unsupervised > K-Means

Then choose your new 12 band multi-date image as the input.

The trick to this method is to choose a large number of classes. Remember, you will have a substantially larger amount of variability with the added temporal dimension than with one image date. It is recommended that you start with a minimum of 75 classes, and then increase incrementally from there (e.g. 100, 125, 150, etc.) up to a maximum of 255.

You can adjust the ***Change Threshold*** as needed, but you will need to add extra iterations for this method to work successfully. Start with 10 iterations and increase the number if needed. Unfortunately, there is no way to find out if ENVI reached the change threshold (i.e. less than 5% of the pixels were changing classes) before running out of iterations. The only way to really check this in ENVI is to open the classified map, and determine if the classes are too 'mixed'.

c. **Label the unsupervised output**.

When the classification is complete, label the classes as usual using the

Overlay > Classification

tool in the image window. Ideally, you are looking for the classes that capture the areas of *change* (e.g. forest to clear-cut). If the stable, *no change* classes are confused, you may wish to merge all of these classes (e.g. water, agriculture, forest, etc. that have not undergone any changes from date 1 to date 2) into one large ***unchanged***

areas class.

A second way to produce better results with this method is to divide up your image into parts, classify the different sections independently and then mosaic the classified change maps back together into one image.

d. **Merge your final classes.**

Once you have completed the labeling step above, go ahead and merge your classes so that you have one final map. Go to the ***Interactive Class Tool*** dialogue box and select:

Options > Merge classes ….

Once the new window appears, select the ***Base Class*** (e.g. class 1), and then select the class(es) in the lower box that you want to merge into that class. For example, if classes 1, 2, and 3 all represent forested areas then classes 2 and 3 (the merge classes) should be mapped to class 1 (the base class). Once you choose a combination between a base and merge class (or several merge classes), click the ***OK*** button.

Be sure to ***Save changes to file*** (under the file menu in the ***Interactive Class Tool***) when you are done labeling and merging. You will need to complete this step before you run the accuracy assessment step below.

6. Accuracy assessment using an independent, random set of test sites

To have an objective means of assessing the different change detection methods, you will perform an accuracy assessment similar to the one you conducted for your supervised classification in Introduction to Environmental Remote Sensing. However, the difference is that your classes are not static areas confined to a single image. Instead, you will label your test sites as *no change* areas and *change* areas. Since you have most likely completed the change maps by this point, you should have a pretty clear idea of what classes you will need to assess. If not, take a moment to determine the classification scheme you need in your final land cover change maps. Then, follow the directions for creating a random sample as outlined in the accuracy assessment lab. Make sure to select a large number of random test points for this analysis. Because the areas of change are likely small with respect to the overall image, you will want to make sure your test site sample is dense enough to capture these areas.

Once you have labeled the random test sites, open the ***Confusion Matrix*** tool. Make sure to match your test sites to their corresponding classes in both of your final land cover change maps (one map from the NDVI differencing method, and one from the unsupervised multi-date technique). Save the two confusion matrices to a text file.

Note: It is possible that your map legends for the two maps may differ slightly. For instance, the differencing process will only yield a large, catch-all *no change* class, while you might be able to differentiate the *no change* classes in the multi-date unsupervised classification (e.g. stable agriculture, stable urban, etc.). You may either adjust your test sites as necessary to accommodate each map, or you may wish to merge your classes so that they are consistent across both/all maps. Either option is fine, but be sure to articulate which procedure you choose, and the steps you followed in your final report.

Remember, do not bias the estimates of class or map accuracy, since you will not be graded on *how high* your accuracy result is. Rather, you will be graded on your understanding, explanation, and discussion of the accuracy assessment results.

7. Assignment

Your assignment is to produce a final report that describes the results of your two maps (including the accuracy assessment confusion matrices), and provides a discussion on the efficacy of the two change detection methods. The report must comply with acceptable standards of technical writing within the geoscience community. The most common organizational form of a scientific report includes an introduction, study area section, methods section, results, and discussion.

Submitting the final report:

For this lab, you must submit your final report electronically by emailing it to the class email account, envst556@gmail.com. Please put your name and the lab number in the subject heading of your email. For student Bucky Badger, the subject line would read:

Bucky Badger – Lab 2

The name of your *word document* must also have the lab number and your name in this format:

Bucky_Badger_lab2.doc