COA 690 / 790 GIS in Marine Science

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2/20/2017

Due: 2/27/2017

Lab 4 Mapping Seagrass Using Remotely Sensed Imagery in ArcGIS[1]

What you need to turn in: Answer to one question and four maps (with title, neatline, north arrow, scale bar, and legend) specified in the lab.

This lab will focus on basic spatial analysis and image processing procedures relevant to the coastal zone. We are going to explore a methodology for mapping the extent of seagrass in Nahant Habor, part of the greater Boston Harbor area in Massachusetts.

Seagrass areas are very sensitive to pollution, particularly pollutants that affect water clarity such as sewage effluent. In the case of Boston Harbor, Massachusetts, seagrass beds have been decimated by years of industrial and sewage pollution. However, there is now an effort to clean the harbor through improved water treatment facilities. It is hoped that the quality of water in the harbor will noticeably improve in the coming years. One way to gauge the degree to which water quality is improving is by documenting the regeneration of seagrass beds.

We will use three bands of remotely sensed video imagery. These images were gathered from a video imaging system mounted aboard a small aircraft. This method of acquiring remotely sensed data is relatively quick and inexpensive. The video product is also better suited to image processing and GIS manipulation than conventional aerial photography. We have raster images (stills from a video tape) from the green, red, and infrared portions of the electromagnetic spectrum at a one meter spatial resolution. Using these three images and Principle Components Analysis (PCA), we will attempt to map the extent of seagrass.

The data we have is reflectance values. That is, the value of each pixel corresponds to the amount of the sun's energy that is reflected back to the sensor. The values range from 0 (no reflectance) to 255 (very high reflectance) for each of the three wavelengths.

Step 1: Exploring the data. Examine each of the following raster files[2]:

GREEN.rst: A raster image from a camera fitted with a green-yellow filter (545 - 555 nm).
RED.rst: A raster image from a camera fitted with a red filter (644 - 656 nm).

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[1] The lab is revised based on the document of "*Applications in Coastal Zone Research and Management*" from Clark Labs at Clark University.
[2] The files with extension of "rst" are for IDRISI GIS software, and they are compatible with ArcGIS.

INFRARED.rst: A raster image from a camera fitted with a filter in the near infrared (846 - 857 nm).

Other files provided in this exercise data set:
SEAGRASS.shp: A vector file map of seagrass locations in Nahant Harbor.

Each of the three bands contains unique information as well as information with a great deal in common. It should be clear in all three that the shoreline runs roughly east to west across the top of the images. Housing developments can be seen to the north of the shore and a large pier is evident in the upper right side of the images.
Different information, however, will come from different places on the electromagnetic spectrum. Bands lower on the electromagnetic spectrum have shorter wavelengths that will penetrate water better than long ones; they will reflect changes in the sea bottom while long wavelengths will indicate where the edge of the water is located. Knowing this, we can expect to see more of the sea bottom in the green and red images than in the infrared image. In particular, if we examine the GREEN image again, we can see that the offshore areas are richly differentiated making it difficult to discern land from water. However, even the shortest wavelengths are eventually absorbed by water as it gets deeper, and we can see reflectance diminish as the water gets deeper. In the INFRARED image, where the longer wavelengths barely penetrate the water at all, we see a sharp contrast between land and water. There is only negligible reflectance over water in this band.

Step 2: We will create a mask of land areas, so we do not need to consider land in the image processing analysis. To create a mask of land areas, we will take advantage of the way water absorbs longer wavelengths.

2.1 Right click "INFRARED", choose properties -> symbology tab -> classified -> classify, so you can see the histogram of the reflectance. Note how the histogram is bi-modal with most of the pixels falling at the low reflectance end of the graph. We can assume, given the above discussion that the large hump at the low reflectance end represents all the water pixels, while the other hump represents land pixels.

To make a Boolean mask of land and water, we estimate some threshold between the two humps of the histogram (use 80 in this lab) and reclassify the infrared image accordingly. Since we are ultimately interested in the water areas, the mask should have the value 1 in those areas and the value 0 in all land areas.

2.2 If you have not turned on "Spatial Analyst" extension, you need to go to ArcMap menu: Tools -> Extensions , and then check "Spatial Analyst".

2.3 Now you have spatial analyst extension on, you can go to "Spatial Analyst Tools" in ArcToolbox, click "+" sign before "Reclass", and then click classify. Use INFRARED as the input raster, choose "Value" in the Reclass Field, give a new value of 1 to all values that range from 0 to just less than 80, and a new value of 0 to all values that range from 80 to just less than 256. Call the result LANDMASK. See Figure 1.

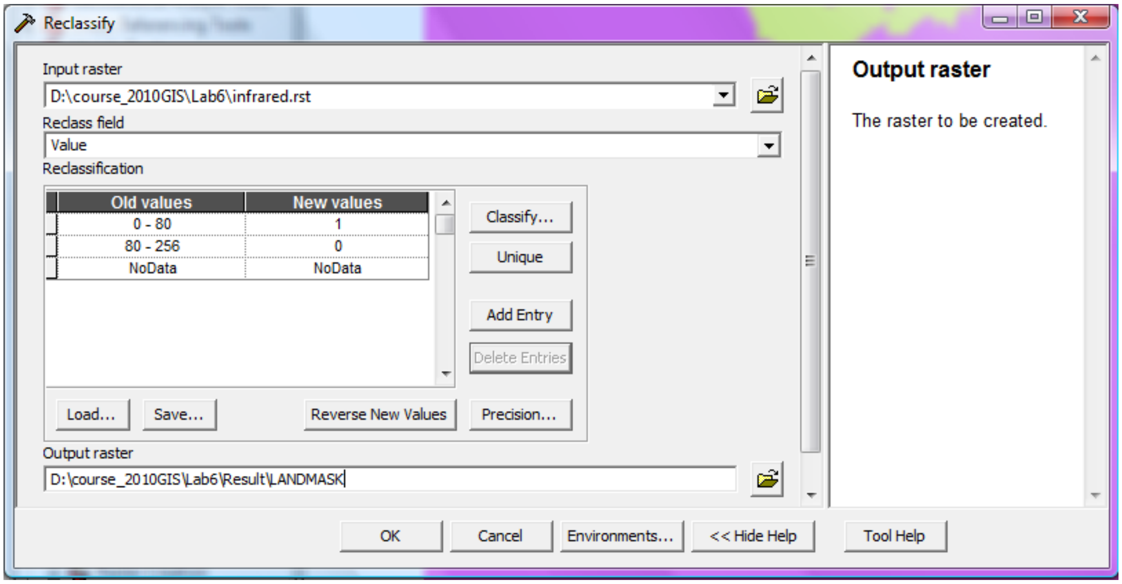

Figure 1

Note that there are many small areas in the land portion of LANDMASK that are confused with water (they may be ponds, or wetlands). It is only the contiguous water body of the harbor with which we are concerned.

Question: ***What would happen if we tried to do the same procedure using the GREEN band?***

We will isolate the contiguous water body of the harbor from the small water areas.

2.4 First, we will convert LANDMASK to polygons: In ArcToolbox, click Conversion Tools -> From Raster -> Raster to Polygon, and then follow Figure 2.

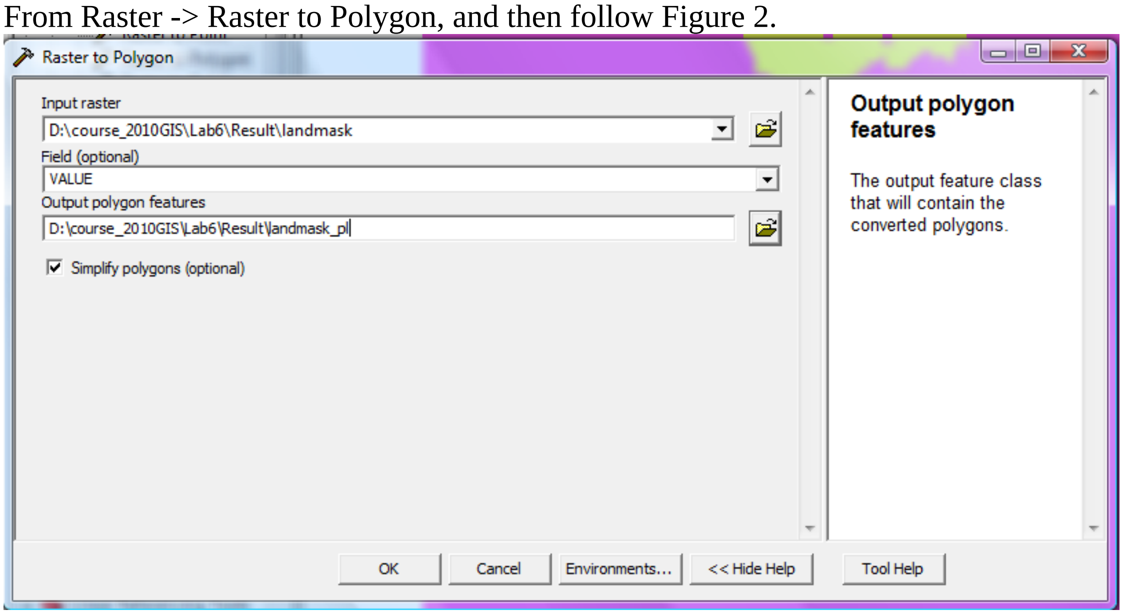

Figure 2

2.5 Next, we will calculate the area for each polygon. In ArcToolbox, click “Spatial Statistics Tools” -> Utilities -> Calculate Areas, and then follow Figure 3.

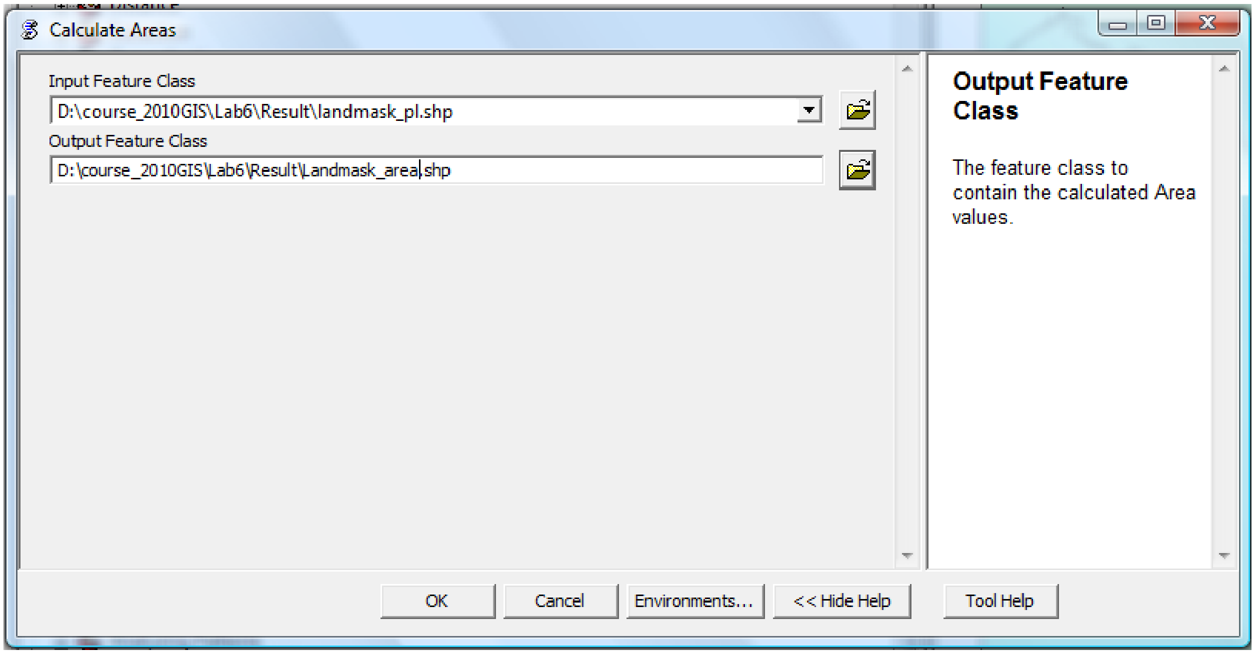

Figure 3

2.6 Right click Landmask_area, and choose “Open Attribute Table”. Right click “F_Area” in the table, and choose “Sort Ascending”. Now you can see the only polygon we are interested in is the one with the largest area. We are going to add a field to store Boolean values, 0 representing the polygons we do not need for our following analysis, and 1 representing the coastal water polygon which we are interested in.

2.7 In the table, click “Options”, choose “Add Field”, and name the new field “AOI” and leave others, and click “OK”. (Figure 4)

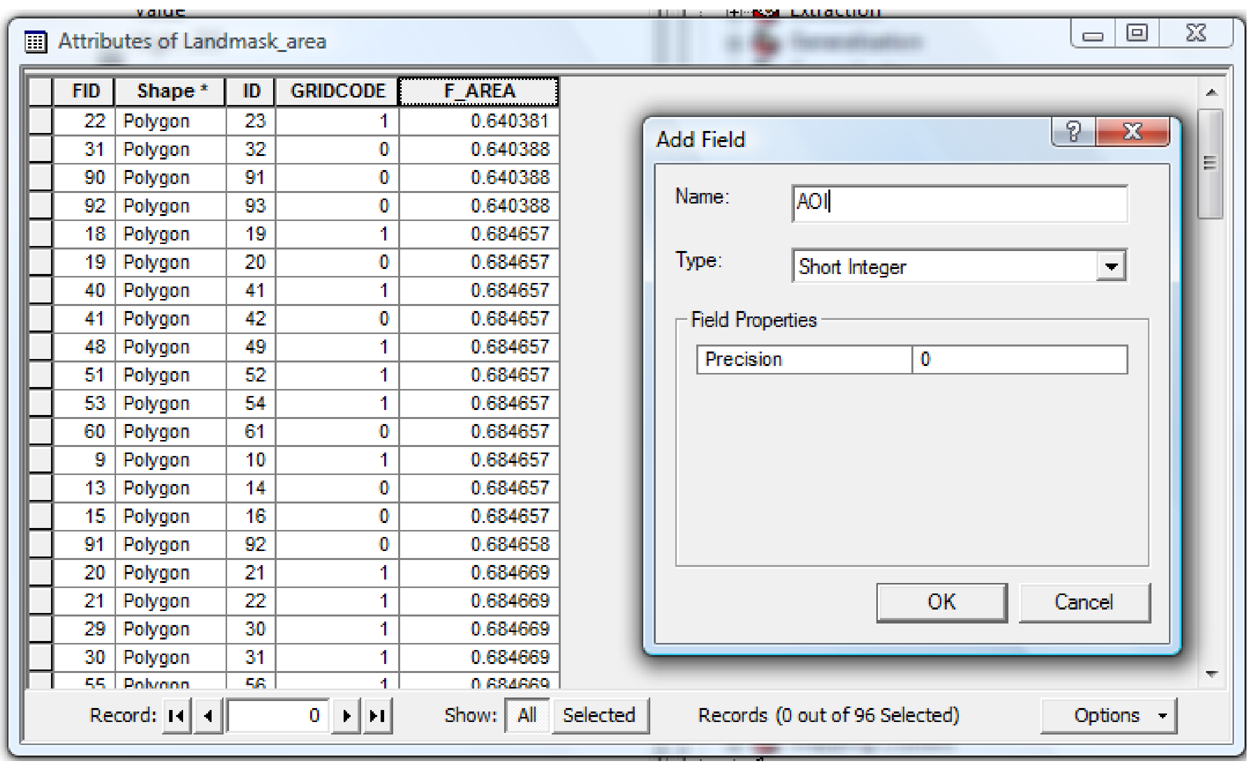

Figure 4

2.8 You may see all the values of AOI are 0 by default, and we need to change its value to 1 in the last row. Go to Editing toolbar, and click "Editor" and choose "Start Editing"(Figure 5), and then select "Shapefiles/dBase files" for Type.

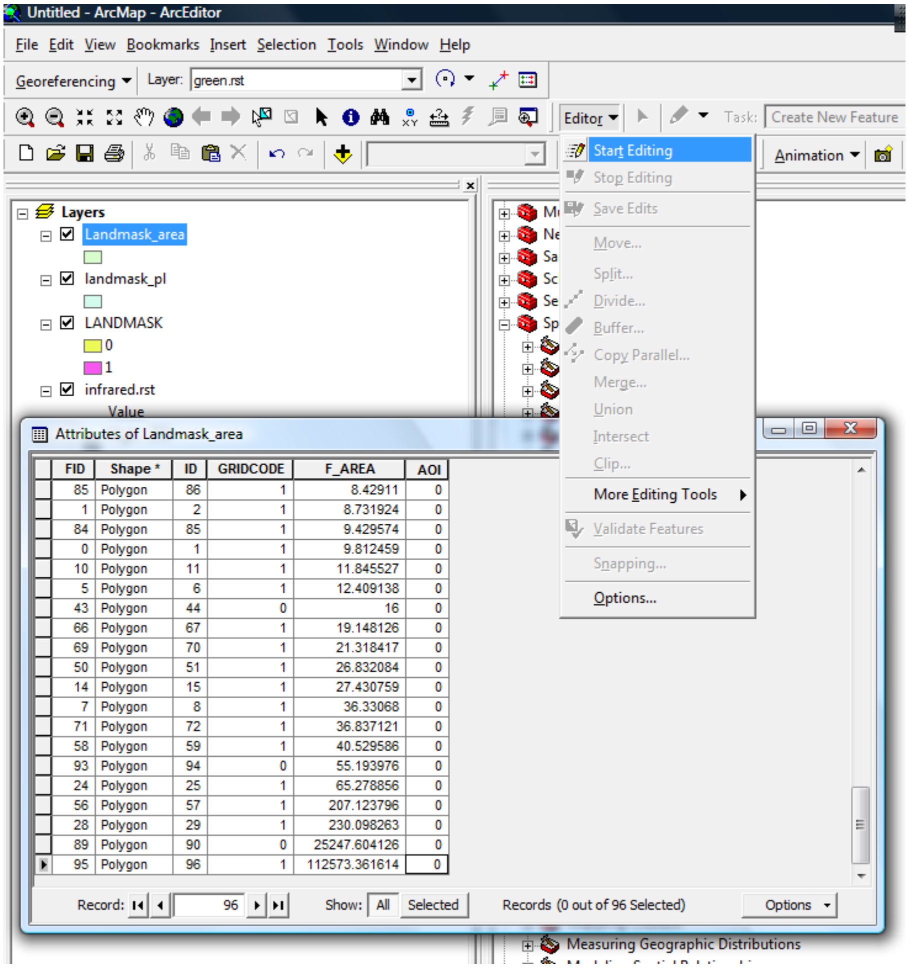

Figure 5

2.9 Now you can change the value in the last row from 0 to 1. Save you edits, and "Stop editing".

2.10 Next step is to convert "Landmask_area" back to raster file using Conversion Tools -> To Raster -> Polygon to Raster. Refer to Figure 6 for the parameters.

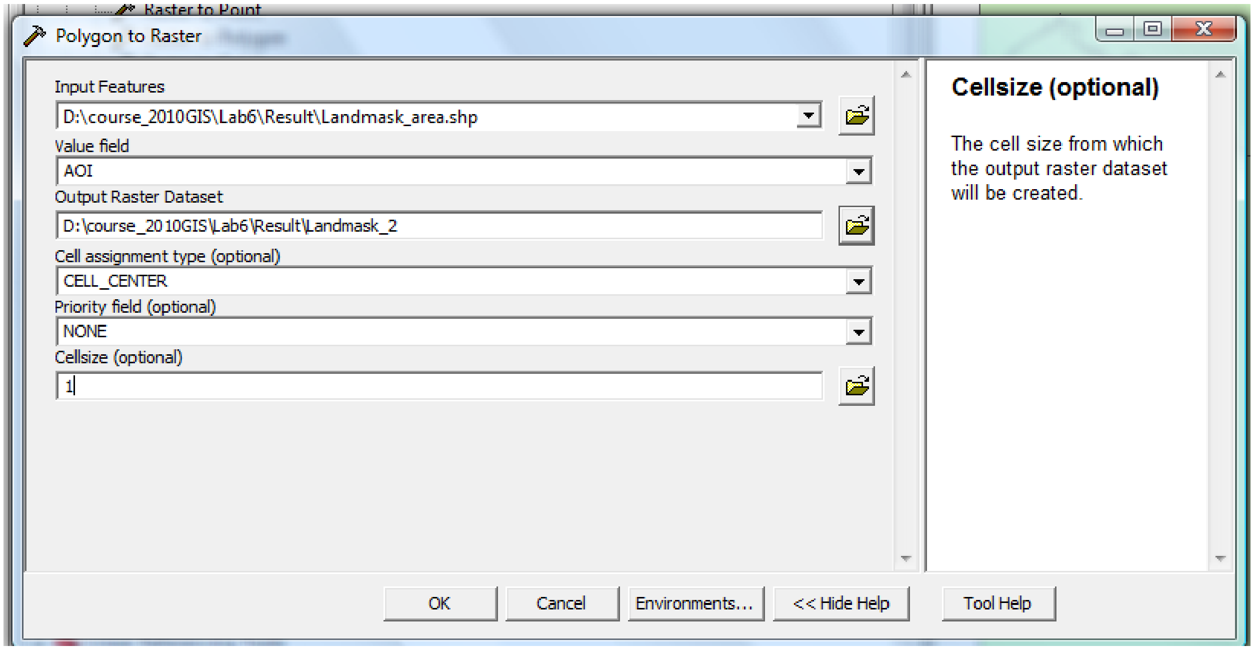

Figure 6

2.11 When you view Landmask_2, you notice some speckles on the land, which are assigned as "NoData", and we need to reclassify these areas to 0. You need to figure out the step yourself (Hints: use "Reclassify" and refer to Step 2.2.)

Print the map of Landmask_2.

2.12 Now you have the mask file ready, and you need to mask the land out for the three bands by multiplying them with the mask file. You need to use Spatial Analyst Tools again: Spatial Analyst Tools -> Math -> "Times", and then follow Figure 7.

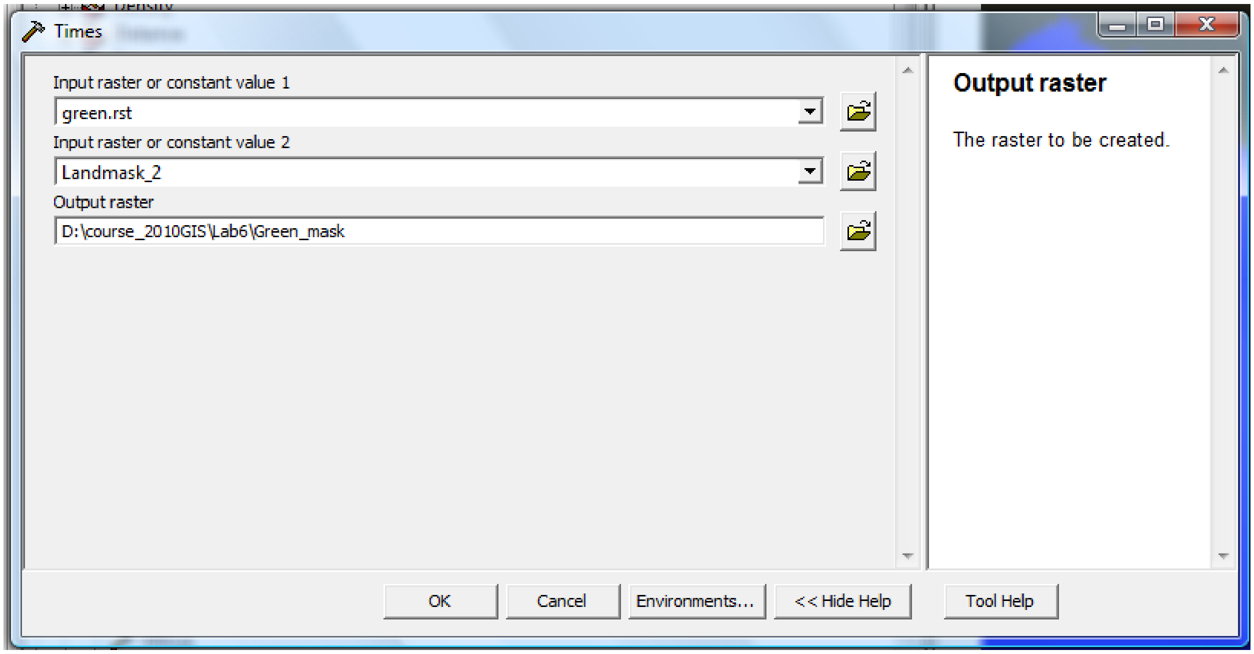

Figure 7

2.13 Perform the same procedure for red band and infrared bands.

Step3: Principal Components Analysis
Based on the discussion by Khan et. al. (1992) and Van Hengel and Spitzer (1991), we will assume that Principal Components Analysis (PCA) can be used to extract bottom types. Also like Khan et. al. (1992), we assume that "the principal variation in water reflectance in the visible wavelength bands is due to changes in water depth, while the secondary variation is due to changes in bottom reflectance" (p. 607). That is, the first component of the PCA, which always explains the most variance in a given set of bands, can be used as an index to water depth.

And the second component, which explains the most variance after the first component has been removed, can be used as an index to bottom type. It is important to stress that this method also works best when the area in question is shallow clear water and when some ground truth data is available.

3.1. Still in “Spatial Analyst Tool”, choose “Multivariate”, and then Principle Component. Then follow Figure 8.

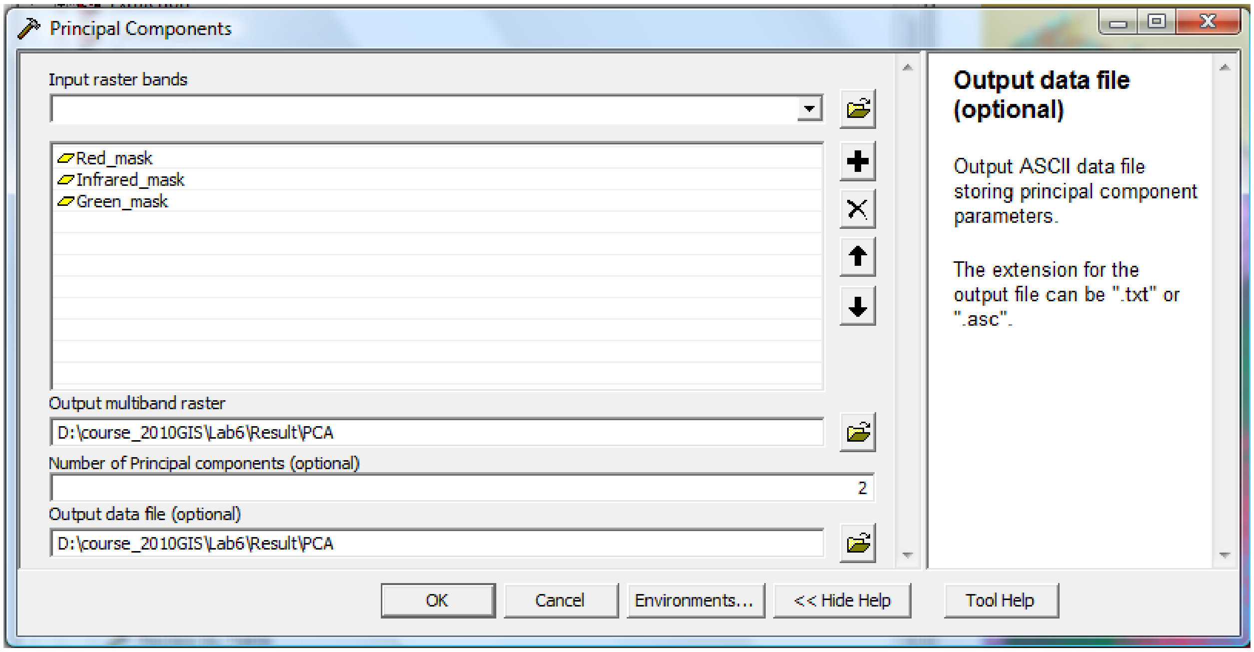

Figure 8

You may examine the display of component 1 or 2 (Stretched: band_1 or band_2) and both (RGB composite) by changing the display properties under "Symbology" tab in layer property window.

This image has values that change in a progression from north/northwest to south/southeast suggesting changing relative water depth. However, it is clear that the area we know to be seagrass is causing some confusion.

3.2 Add SEAGRASS vector file in ArcMap. Within this area, the trend is still from shallow to deep water, but the scale is shifted such that it appears deeper than it should.

3.3 Now examine component 2. This image has values that change not with water depth, but from left to right, suggesting changes in bottom type.

Here the seagrass area is more uniformly represented and is clearly differentiated from the large dark area west of it which we know is at a similar depth.

Print the maps of component 1, 2, and both.

References

Khan, M. A., Y. H. Fadlallah, and K. G. Al-Hinai. 1992. "Thematic Mapping of subtidal Coastal Habitats in the Western Arabian Gulf using Landsat TM data -- Abu Ali Bay, Saudi Arabia." International Journal of Remote Sensing, 13(4): 605-614.
Van Hengel, W. and D. Spitzer. 1991. "Multi-temporal Water Depth Mapping by Means of Landsat TM." International Journal of Remote Sensing, 12 (4): 703-712.